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Compendium of Results From Firing Different Explosively Formed Projectiles

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ABSTRACT

This compendium assembles the results from a series of firings utilising different variations of Explosively Formed Projectiles (EFP'S). Variations were applied to the design of the liner, casing and explosive.
Following computer numerical modelling, short listed candidates were manufactured and fired into steel witness plates. The results were then tabulated accordingly. Also used during the firing phase was Flash radiography (FXR) to study velocity and flight characteristics.

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Compendium of Results From Firing Different Explosively Formed Projectiles

Executive Summary

There is a growing appreciation for the use of Explosively Formed Projectiles (EFP'S) in military and civilian applications today. For example, EFP's can be found in various missile systems, detonators, and demolition charges. The original tasking that led to this report was for the application of EFP's to explosive ordnance disposal (EOD) operations.

This compendium brings together the results, (in a tabulated format), produced by firing various EFP's into a steel witness plate. It does not make recommendations as to which style may be better than another but will enlighten the reader and charge designers as to the possible performance of several different combinations of constraints applied to the liner design, casing and explosive. By no means does this compendium cover all the combinations available and this report should demonstrate that fact.

The study used finite element modelling (PC-DYNA 2D) to achieve a list of potential candidates for further investigation. These were manufactured and tested in the explosive firing chambers at DSTO. The set up involved firing the charges at different standoff distances above the steel plate, and multiple flash radiography (FXR) to capture the EFP in flight to record a velocity.

Once the firings were completed the witness plates were sectioned in half and the depth of hole, entry diameter and profile of the hole were obtained. The results are all tabulated and presented in the Appendix 1.

The results demonstrate that changing any characteristic of an EFP design, such as liner profile, material or amount of explosive used will influence the performance.

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Darren McQueen joined DSTO in 1987 as a technical officer and since graduated with a Bachelor of Technology in Mechanical Engineering and Management from Deakin University in 2001. He has worked on investigations into the effectiveness of explosive filled ordnance, explosively formed projectiles for low order dispoal techniques, seamine neutralisation research and vehicle and personnel vulnerability to landmines.

Contents

1. Introduction

The concept of Explosively Formed Projectiles (EFP's) uses explosive energy to deform a metal plate into a coherent penetrator while accelerating it to velocities up to 3000m/s [1]. Unlike traditional shaped charges, which tend to form long rod penetrators, an EFP will put most of its original mass into forming what appears to be a solid mass or slug (however its true form in some variants may also be likened to that of a hollow sheath).

The final shape and performance of the EFP will depend upon a number of parameters. These include the type and amount of explosive used, case confinement and material, liner shape, thickness, profile, material and peculiarities applied to the liner such as localised heat treatment or performance enhancing grooves.

It can be seen from this list of parameter variables that an in-exhaustive variety of charges could be created and used for a similar number of applications. However this compendium will only present a range of results that were investigated for a specific application. That being, a penetrator that could produce a large diameter hole with respect to the size of the charge and be able to penetrate approximately 15mm of mild steel for the purpose of explosive ordnance disposal (EOD).

Computer modelling [2] was applied and the DYNA 2D hydrocode became a very useful tool in evaluating specific charges. Once a charge design had been agreed upon, its parameters were fed into the hydrocode and the results produced from this code demonstrated the expected penetrator in flight and the expected profile into mild steel.

2. Experimental

2.1 Hydrocode modelling

The design and penetration of many of the candidate configurations were modelled using the Dyna 2D hydrocode. Table 1 lists the material models used for the explosive, liner and case materials. Although the explosive PE4 (88% RDX/11% plasticizer/1% pentaerythritol di-oleate) was used, no material model data exists for computational predictions and therefore the material data for Composition C4 was used in the computations since it has a similar composition (91% RDX/9% polyisobutylene). The initial aim of the Dyna modelling was to produce a liner and projectile that could be used for explosive ordnance disposal (EOD) by creating a low order event. A large number of EFP designs were modelled. Variable parameters were liner design and material and explosive configuration and confinement. Suitable designs were fabricated and the computational predictions were validated using flash radiography instrumented firings to determine projectile shape, velocity and stability during flight.

Table 1. Material data used in EFP simulations.

	Copper	Composition C4	Aluminium	Plexiglass
Material Model	Johnson-Cook	High Explosive Burn	Steinberg-Guinan	Steinberg-Guinan
Equation of State	Gruneisen	JWL	Gruneisen	Gruneisen

2.2 Set up

The penetration capability of the EFP is directly related to its shape and velocity at impact and to obtain a particular profile, all the varying parameters of the EFP design must first be considered. Influence of the parameters on EFP performance were first investigated computationally. All charges utilised the plastic explosive filling known as PE4.

The components for the charge design wherever possible were always based on common commercially available materials. The simple charge, as seen in figure 1, is based upon a detonator locator made of Perspex, a cylindrical charge case of an appropriate length of aluminium (usually 3mm thick) and various liners. The major parameters investigated included thickness, profile and material of the liner. The types of materials considered included high conductivity copper, aluminium to grade 5005, low carbon steel to grade 1010, magnesium, zirconium, borosilicate glass and various forms of plastics.

Validation of the modelling using the manufactured components was carried out inside a small scale firing chamber and involved placing the charge, (hand filled with PE4) on a PolyVinylChloride (PVC) tube which stood on a mild steel witness block. For each firing, the length of the PVC tube was varied according to a multiple of the charge diameter to provide a series of results over different standoff distances. Figure 2 demonstrates the basic set up of the charge, the PVC tube, steel witness plate and the Flash X-Ray (FXR) cassettes used in each of the test firings.

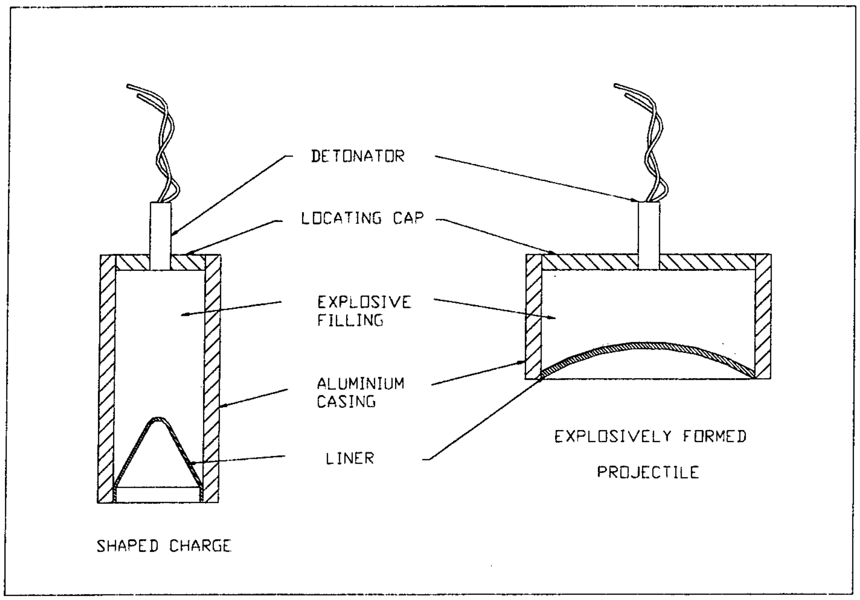


Figure 1 Simple charge design.

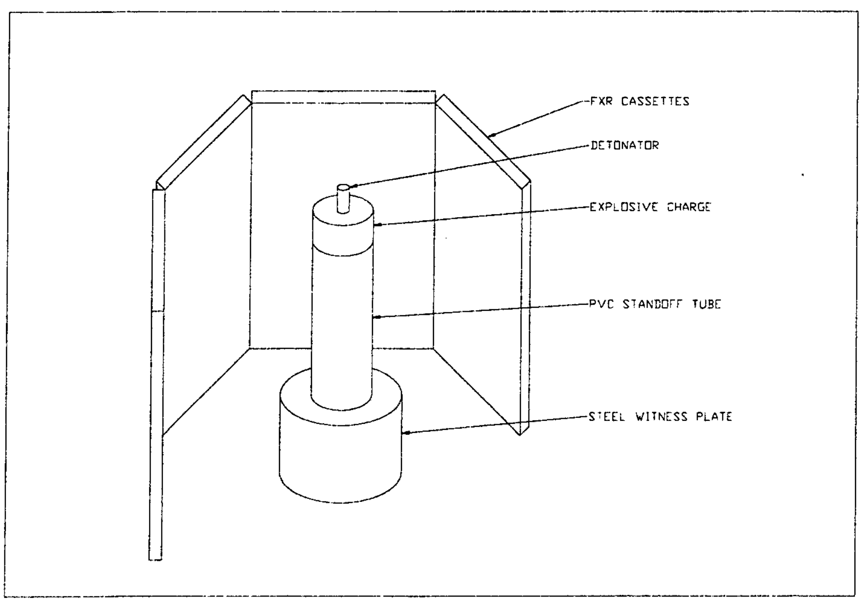


Figure 2 Charge set up.

2.2 Flash Radiography

Four flash x-ray cassettes were placed around the charge (figure 3) to capture the EFP projectile in flight and to calculate the velocity of the projectile. These experiments were carried out using a four-channel FXR system comprising two orthogonal 300kv and two orthogonal 600kv pulsers. Arranged around the central axis of flight, as shown in figure 3.

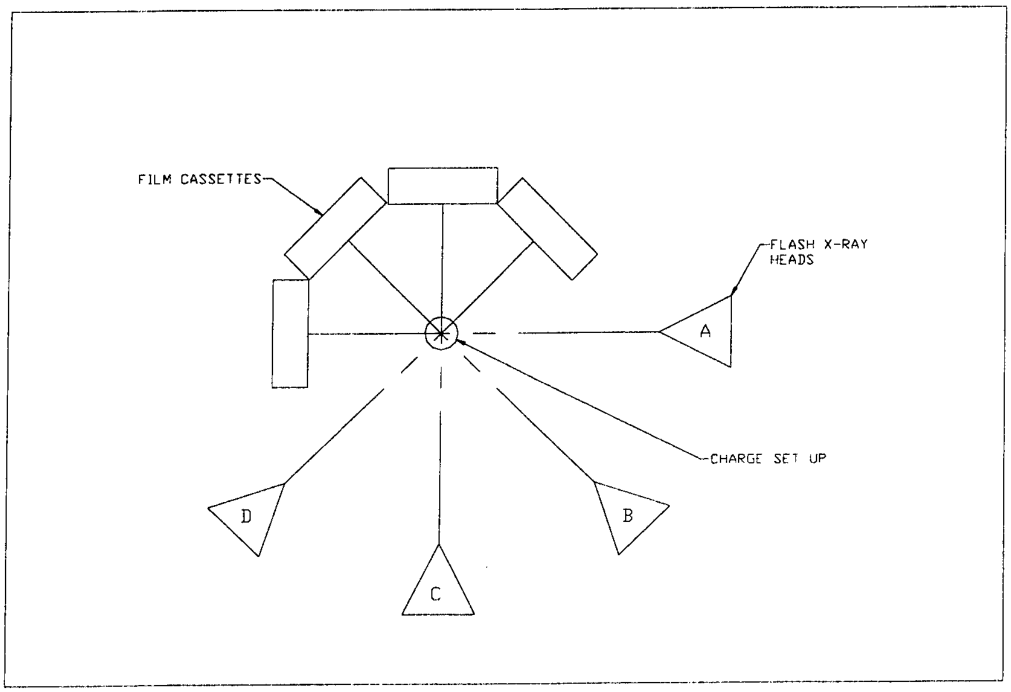


Figure 3 Set-up of the charge and FXR cassettes.

The FXR pulsers were triggered electrically from the firing signal to an Exploding Bridgewire (EBW) detonator. A time delay for the EFP to reach nominal positions was estimated using the computer modelling. These estimates were used as the triggering delays for the FXR, and allowed comparison of expected positions with actual positions. Images were recorded by a film and the florescent intensifying screen combination placed in a protective cassette and positioned near the charge. EFP projectile velocities were calculated from the radiographic images and recorded times [3].

3. Results and Discussion

Once the experiments were completed the witness blocks were sectioned in half longitudinally. Sectioning allowed measurement of the entry hole diameter, depth of penetration to the deepest point of the hole and the profile of the hole to be recorded.

The depth of penetration was taken from the horizontal of the block face and not the crest of the expelled metal wave created around the hole. Each firing was carried out once and the results presented represent that firing and not a series of firings with the same liner and set-up conditions.

Once all the firings of a given charge were completed, the information was collated and presented in the form of penetration profile charts, these profile charts are presented in appendix 1. These charts represent a graphical presentation setting out all the recorded data and hole profiles for each of the charges tested. In many cases, profile charts were completed to have a comparative record of between liners of a similar design but with a single parameter varied.

Modelling and experimental firings have investigated a large range of parameters that can be applied to EFP design. They have included;

1. liner geometry and material,

2. case confinement, and

3. charge diameter and length.

Each variation will affect the performance of the EFP differently. Comparing several penetration profile charts of the same liner but with differing amounts of explosive behind the liner, head height, it can be seen that there is a difference in the penetration performance and velocity. Increasing the amount of explosive used increases the velocity of the EFP projectile, elongation of the shape of the EFP, thus creating a deeper and narrower hole. Altering the case thickness or case material, again would change the penetration performance. It can be seen that as the case material increases in density or thickness, there will be an increase in velocity, penetration and narrowing of the entry diameter. These observations indicate that the manipulation of the detonation front through the explosive will change the result achieved by the liner. Only a small number of variations were investigated as time was limited and there was a specific requirement to develop an EOD technique.

Flash radiography provided many detailed images of EFP's in flight. Images of solid projectiles, hollow projectiles, long rod projectiles and fragmenting projectiles were obtained and compared to the modelling predictions. The agreement was generally quite good and a typical example of the radiographs is shown in figure 4. However, the FXR did have a few problems trying to resolve some of the lower density projectiles in both the glass and plastics range of liners.

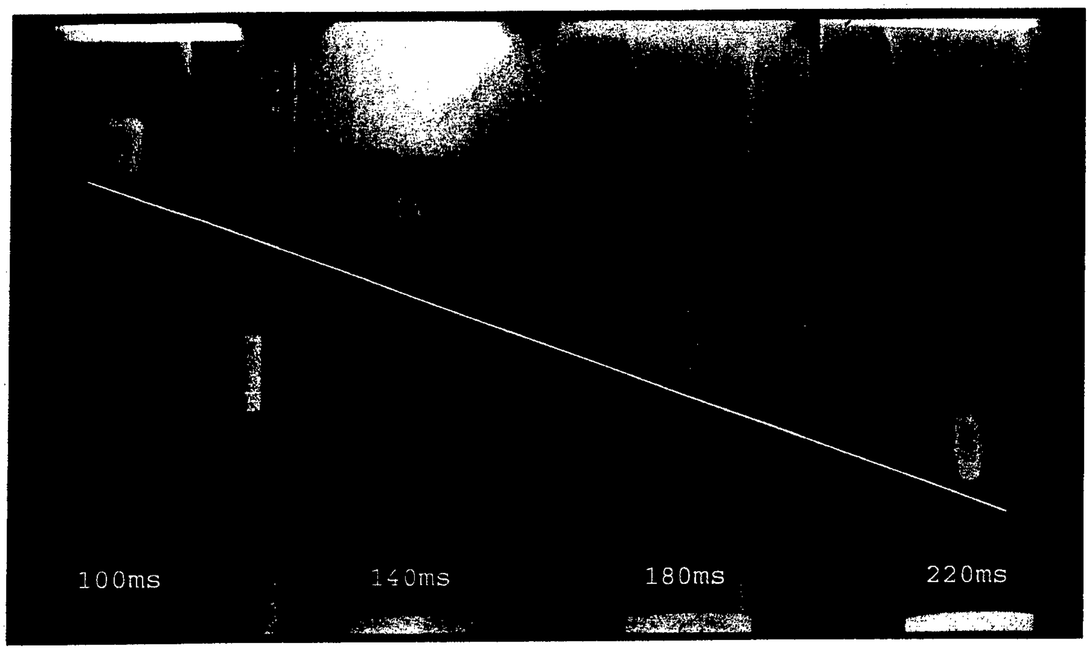
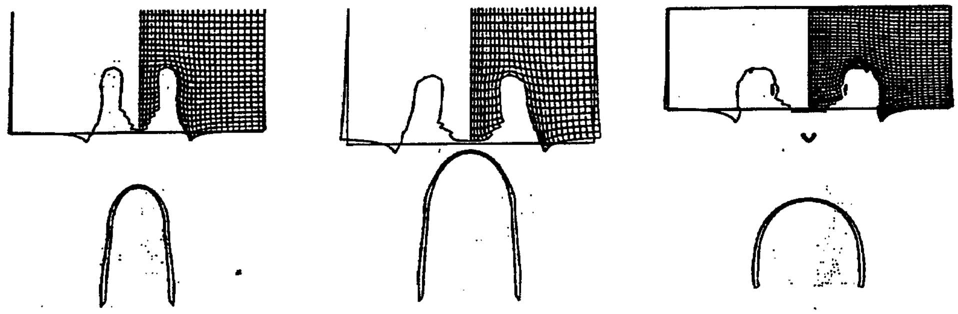


Figure 4 Flash x-ray images of the projectile from a conventional copper EFP.

Figures 5 and 6 demonstrate the modelling results obtained from Dyna and these can be traced against the x-ray images of the EFP's, during flight through air. It was somewhat difficult to compare the interior shapes of some of the projectiles as they are not fully visible on the FXR due to varying material densities. However the predicted shape and size of the EFP's at different time sequences agree reasonably well with the x-ray tracings when placed alongside each other. Likewise, a good correlation with experiment of the EFP impact velocity was achieved. The complete EFP formation process according to the numerical simulation requires around 80 to 100μs after initiation with subsequent projectile velocity stabilisation. A minor discrepancy that was observed is that the predicted EFP's appeared to have collapsed sooner than the experimental projectile. This may be due to a delay in the detonator functioning time that results in a temporal displacement in the comparison.



(a) 60 mm diameter liner (b) 80 mm diameter liner (c) 80 mm diameter liner

Figure 5 *Dyna 2D outputs for the penetration into mild steel of three different designs of EFP's. The liner diameters are as indicated with variation in the charge diameter and the geometry of the liner contour radii giving rise to the different penetration profiles.*

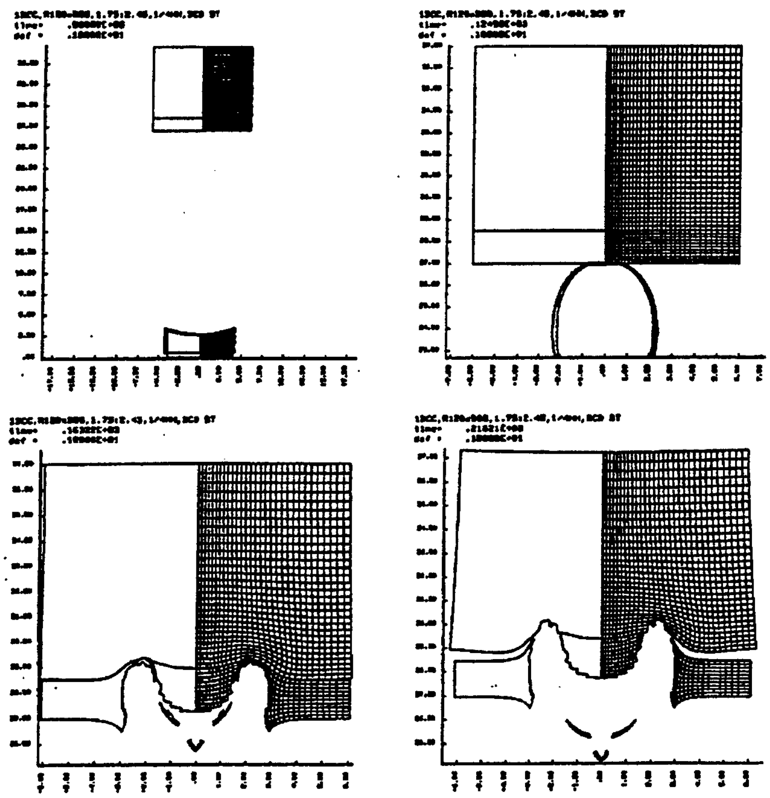


Figure 6 *Dyna 2D penetration of a mild steel target by a low carbon steel donut liner (intervals of approximately 50 microseconds).*

4. Conclusions

This compendium has brought together the results of a large body of work involving computer modelling, manufacture, experimental validation and data analysis with respect to EFP performance. It demonstrates that changing one parameter at a time, varies the velocity of the jet/slug, the penetration into steel and/or the shape of hole produced. These variations have a dramatic affect on the final outcome where for EOD operations could mean the difference between a detonation or a low order burn of the explosive filling.

Although only a relatively small number of firings with respect to the number of possible variations were undertaken in this study, the information provided offer the reader an enlightened view of the expected performance of various EFP designs.

5. Acknowledgments

The author would like to express their gratitude to Mr. Mick Chick for his guidance, Mr. Tim Bussell and Mrs. Lyn McVay for their assistance experimentally, Mr. Chanphu Lam for his valuable assistance with the computer modelling and Mr. Trevor Kinsey for his guidance with the flash radiography.

6. References

[1] Carleone, J., Tactical Missile Warheads, volume 155, Progress in Astronautics and Aeronautics.

[2] Lam, C., and McQueen, D. Numerical Simulations of the Formation and Penetration of Explosively Formed Projectiles, Proceedings of the Seventh Biennial Conference of Computational Techniques and Applications: CTAC 95.

[3] Chick, M., Bussell, T., McQueen, D. and Lam, C. The Cookie-Cutter Explosively Formed Projectile: Its Development and Applications including Explosive Ordnance Disposal, DSTO-TR-0919, February 2000.

Appendix A

Index to penetration profile charts:

Abbreviations;PMMA – Perspex
dia. - diameter
alum - aluminium
thk - thick
H.H. - Head Height
* - incomplete chart

PVC – Polyvinyl chloride
deg - degrees
Hemi – Hemispherica
R - radius
c.d. - charge diameter
S.D. – Standoff

1. Copper liners

- 38mm dia x 42 deg x 1.0mm thk x 2/3 c.d. H.H. x alum case
- 38mm dia. x 90 deg x 1.0mm thk x 2/3 c.d. H.H. x alum case
- 38mm dia. x 140 deg x 1.0mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x flat disc x 1.0mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x flat disc x 1.5mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x R80 x 1.0mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x R40 x 1.0mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x R40 x 1.0mm thk x 1 c.d. H.H. x alum case - segmented grooves
- 38mm dia. x R40 x 1.0mm thk x 1/2 c.d. H.H. x PMMA case
- 38mm dia. x R30 x 0.9mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x R30 x 0.9mm thk x 1/2 c.d. H.H. x alum case
- 38mm dia. x R30 x 1.6mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x R25 x 1.0mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x Hemi. x 1.0mm thk x 1c.d. H.H. x alum case
- 60mm dia. x R60 x 2.0mm thk x 1/4 c.d. H.H. x alum case
- 60mm dia. x R60 x 2.0mm thk x 1/3 c.d. H.H. x alum case
- 60mm dia. x R60 x 2.0mm thk x 1/3 c.d. H.H. x PMMA case
- 60mm dia. x R60 x 2.0mm thk x 1/3 c.d. H.H. x alum case - water penetration
- 60mm dia. x R60 x 2.0mm thk x 2/3 c.d. H.H. x alum case
- 60mm dia. x R60 x 2.0mm thk x 1/3 c.d. H.H. x alum case - 1/16in rubber backed
- 80mm dia. x R80 x 2.0mm thk x 1/4 c.d. H.H. x alum case
- 40mm dia. x Contour (2.0 - 1.0) x 1/4 c.d. H.H. x alum case

2. Aluminium liners

- 38mm dia. x 140 deg x 1.0mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x R40 x 1.0mm thk x 1 c.d. H.H. x alum case

- 38mm dia. x R30 x 1.0mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x R25 x 1.0mm thk x 1 c.d. H.H. x alum case
- 38mm dia. x Hemi x 1.0mm thk x 1 c.d. H.H. x alum case

3. Low carbon steel liners

- Mk 2 Mod 1 Point Focal Charge
- 40mm dia. x Contour (2.0 - 1.5) x 1 c.d. H.H. x alum case
- 38mm dia. x R40 x 1.95mm thk x 1 c.d. H.H. x alum case
- 60mm dia. x R60 x 1.95mm thk x 1/3 c.d. H.H. x alum case
- 60mm dia. x R60 x 1.95mm thk x 1/2 c.d. H.H. x alum case
- 60mm dia. x R60 x 1.95mm thk x 1/2 c.d. H.H. x PMMA case

4. Contoured liners (low carbon steel)

- 25mm dia. x TUB 20 x 1/2 c.d. H.H. x alum case
- 60mm dia. x TUB 04 x 1/3 c.d. H.H. x alum case
- 60mm dia. x Type A x 1/3 c.d. H.H. x alum case
- 60mm dia. x Type B x 1/4 c.d. H.H. x alum case
- 80mm dia. x Type C x 1/4 c.d. H.H. x alum case
- 80mm dia. x TUB 12 x 1/4 c.d. H.H. x alum case
- 80mm dia. x TUB 13C x 1/4 c.d. H.H. x alum case
- 80mm dia. x TUB 17 x 1/4 c.d. H.H. x alum case
- 80mm dia. x Refined x 1/4 c.d. H.H. x alum case
- 80mm dia. x Refined x 1/4 c.d. H.H. x PMMA case

5. Glass liners

- 60mm dia. x 90 deg x 2.0mm thk x 1/3 c.d. H.H. x alum case
- 60mm dia. x 60 deg x 4.0mm thk x 1/3 c.d. H.H. x alum case
- 60mm dia. x 90 deg x 4.0mm thk x 1/4 c.d. H.H. x alum case
- 60mm dia. x 90 deg x 4.0mm thk x 1/3 c.d. H.H. x alum case
- 60mm dia. x 105 deg x 4.0mm thk x 1/4 c.d. H.H. x alum case
- 60mm dia. x 105 deg x 4.0mm thk x 1/3 c.d. H.H. x alum case
- 60mm dia. x 110 deg x 4.0mm thk x 1/3 c.d. H.H. x alum case
- 60mm dia. x 120 deg x 4.0mm thk x 1/4 c.d. H.H. x alum case
- 60mm dia. x 120 deg x 4.0mm thk x 1/2 c.d. H.H. x alum case
- 60mm dia. x Hemi x 4.0mm thk x 1/4 c.d. H.H. x alum case

6. Pyrophoric liners

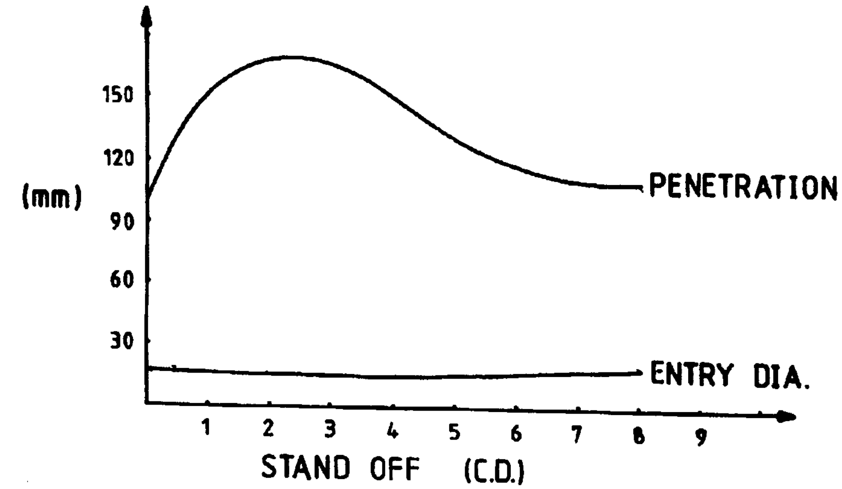
- 60mm dia. x R40 x 4.0mm thk x 1/3 c.d. H.H. x alum case x cast magnesium
- 60mm dia x R60 x 4.0mm thk x 1/3 c.d. H.H. x alum case x cast magnesium
- 60mm dia. x R60 x 4.0mm thk x 1/2 c.d. H.H. x alum case x cast magnesium
- 60mm dia. x R60 x 3.3mm thk x 1/3 c.d. H.H. x alum case x zirconium
- 60mm dia. x R60 x 3.3mm thk x 1/2 c.d. H.H. x alum case x zirconium
- 60mm dia. x R40 x 4.0mm thk x 1/3 c.d. H.H. x alum case x sheet magnesium
- 60mm dia. x R40 x 4.0mm thk x 1/3 c.d. H.H. x alum case x aluminium

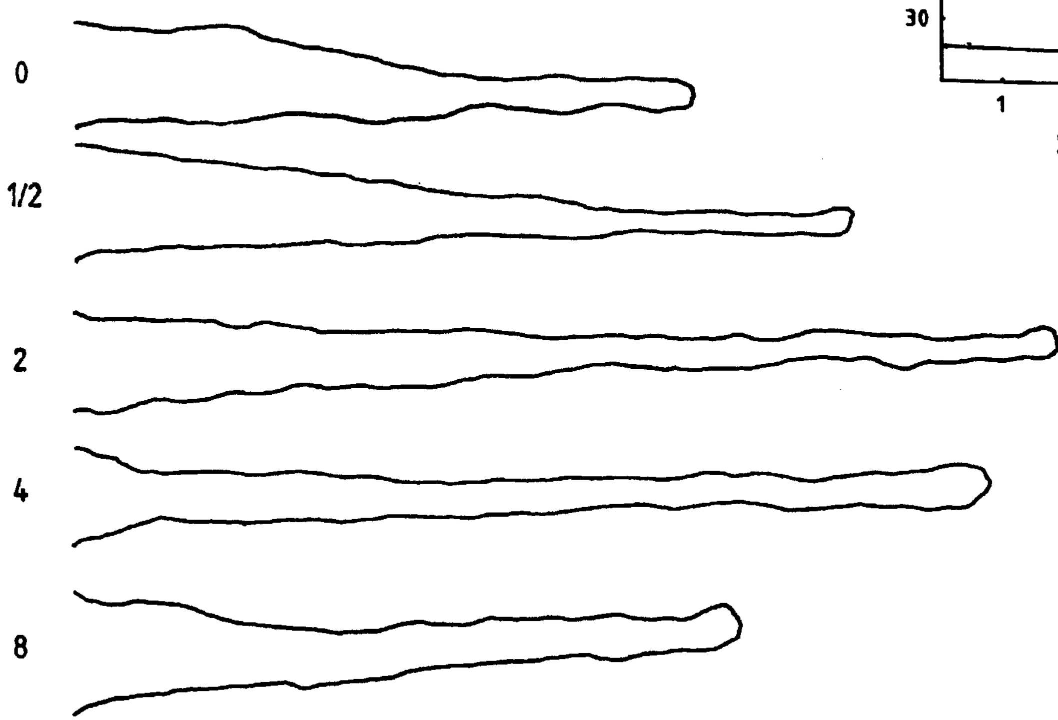
7. Plastic liners

- 38mm dia. x 90 deg x 1.0mm thk x 52mm H.H. x alum case x Teflon
- 38mm dia. x R40 x 1.0mm thk x 66mm H.H. x alum case x Teflon
- 38mm dia. x 90 deg x 1.0mm thk x 52mm H.H. x alum case x Nylon
* 38mm dia. x R40 x 1.0mm thk x 66mm H.H. x alum case x Nylon
* 38mm dia. x 140 deg x 1.0mm thk x 64mm H.H. x alum case x Nylon
* 38mm dia. x Hemi x 1.0mm thk x 52mm H.H. x alum case x Nylon
* 38mm dia. x 90 deg x 1.0mm thk x 52mm H.H. x alum case x Polyethylene
* 38mm dia. x 90 deg x 2.0mm thk x 52mm H.H. x alum case x Polyethylene
* 38mm dia. x 90 deg x 3.0mm thk x 52mm H.H. x alum case x Polyethylene
* 38mm dia. x 140 deg x 1.0mm thk x 64mm H.H. x alum case x Polyethylene
* 38mm dia. x R40 x 1.0mm thk x 66mm H.H. x alum case x Polyethylene
* 38mm dia. x Hemi x 1.0mm thk x 52mm H.H. x alum case x Polyethylene
- 38mm dia. x 90 deg x 1.0mm thk x 52mm H.H. x alum case x PVC
- 38mm dia. x 90 deg x 2.0mm thk x 52mm H.H. x alum case x PVC
- 38mm dia. x 90 deg x 3.0mm thk x 52mm H.H. x alum case x PVC
* 38mm dia. x 90 deg x 4.0mm thk x 52mm H.H. x alum case x PVC
* 38mm dia. x 90 deg x 5.0mm thk x 52mm H.H. x alum case x PVC
* 38mm dia. x 90 deg x 6.0mm thk x 52mm H.H. x alum case xPVC
- 38mm dia. x 140 deg x 1.0mm thk x 64mm H.H. x alum case x PVC
- 38mm dia. x 140 deg x 1.0mm thk x 52mm H.H. x alum case x PVC
* 38mm dia. x 105 deg x 1.0mm thk x 52mm H.H. x alum case x PVC
- 38mm dia. x 75 deg x 1.0mm thk x 46mm H.H. x alum case x PVC
- 38mm dia. x 60 deg x 1.0mm thk x 38mm H.H. x alum case x PVC
- 38mm dia x 45 deg x 1.0mm thk x 25mm H.H. x alum case x PVC
- 38mm dia. x R40 x 1.0mm thk x 66mm H.H. x alum case x PVC
- 38mm dia. x Hemi x 1.0mm thk x 33mm H.H. x alum case x PVC
* 38mm dia. x 90 deg x 1.0mm thk x 52mm H.H. x PMMA case x PVC
- 38mm dia. x 90 deg x 1.0mm thk x 1 c.d. S.O. x alum case x PVC - varying H.H.

42° COPPER LINER (ϕ 38 mm)

STAND OFF (C.D.)	0	1/2	2	4	8
ENTRY DIAMETER (mm)	17	18	16	15	20
PENETRATION (mm)	103	130	165	152	112





50 mm SCALE

HOLE PROFILES

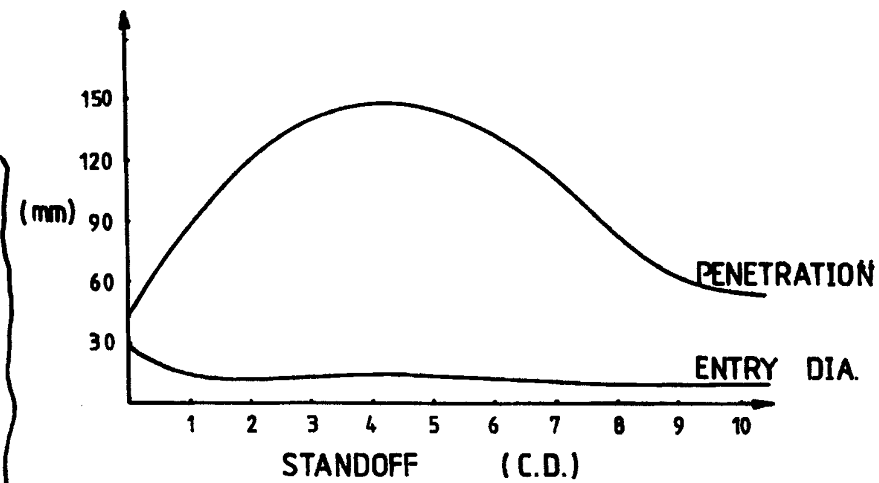
J.T.V. = 7·4 mm/μs

CHARGE FILLED TO
2/3 C.D. HEAD HEIGHT.

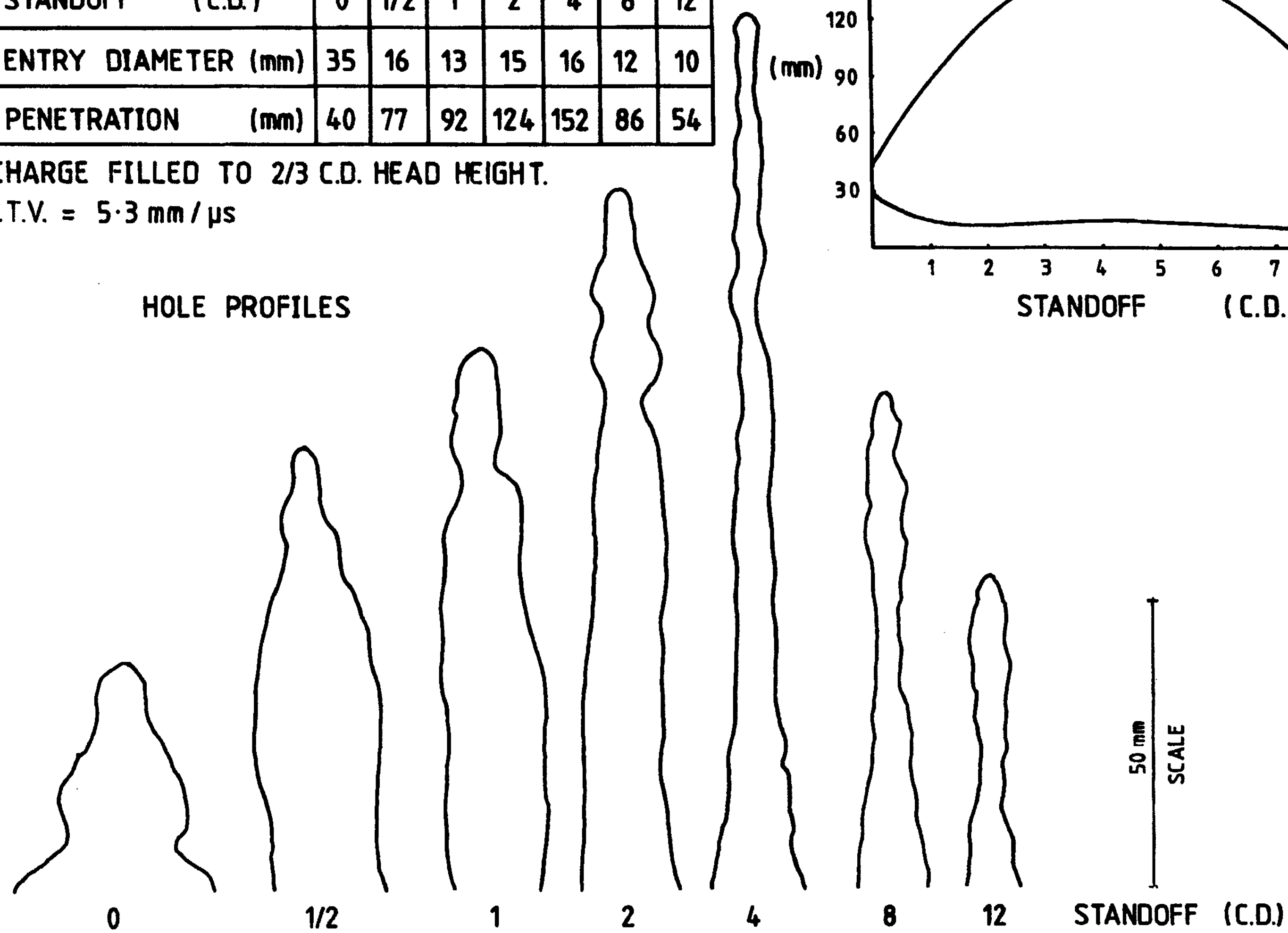
90° COPPER SHAPED CHARGE (Ø38mm)

STANDOFF (C.D.)	0	1/2	1	2	4	8	12
ENTRY DIAMETER (mm)	35	16	13	15	16	12	10
PENETRATION (mm)	40	77	92	124	152	86	54

CHARGE FILLED TO 2/3 C.D. HEAD HEIGHT.
J.T.V. = 5·3 mm/μs



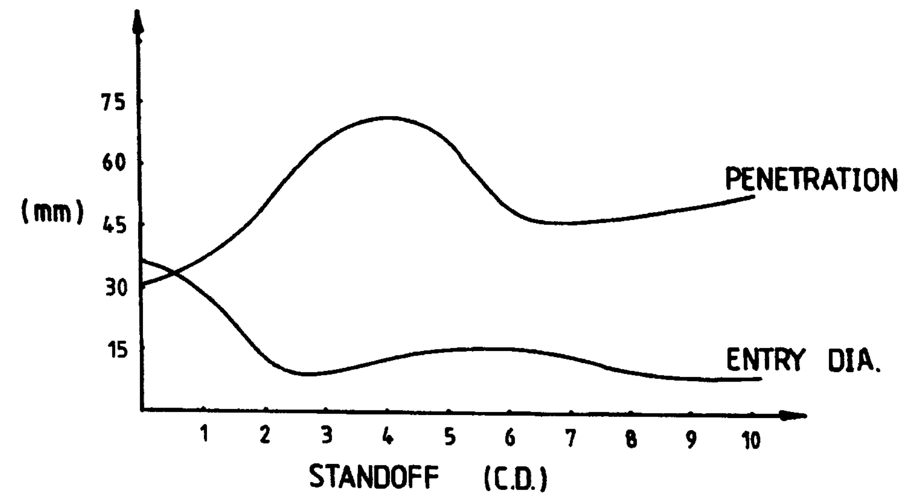
HOLE PROFILES

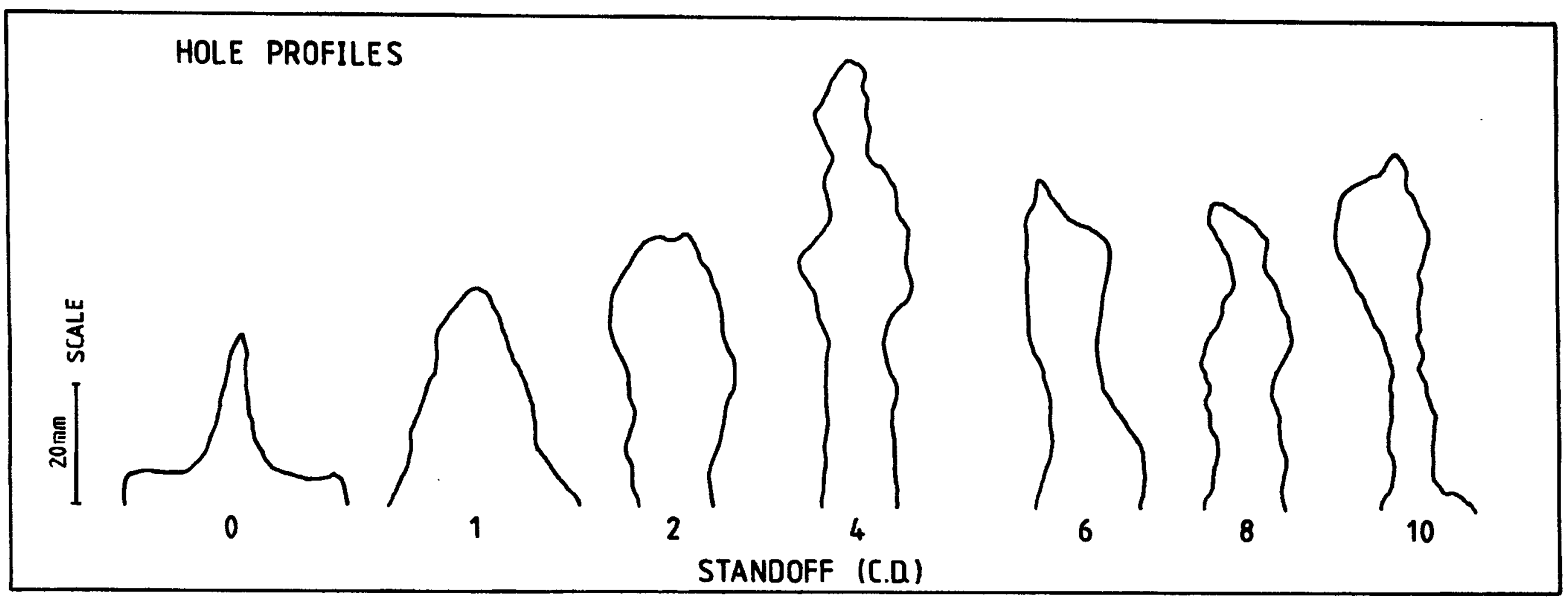


140° COPPER LINER

STANDOFF (C.D.)	0	1	2	4	6	8	10
ENTRY DIAMETER (mm)	36	32	14	12	17	13	11
PENETRATION (mm)	30	34	42	71	52	49	53

J.T.V. = 2·7 mm/µs
CHARGE 38mm dia. WITH 1C.D. HEAD HEIGHT.

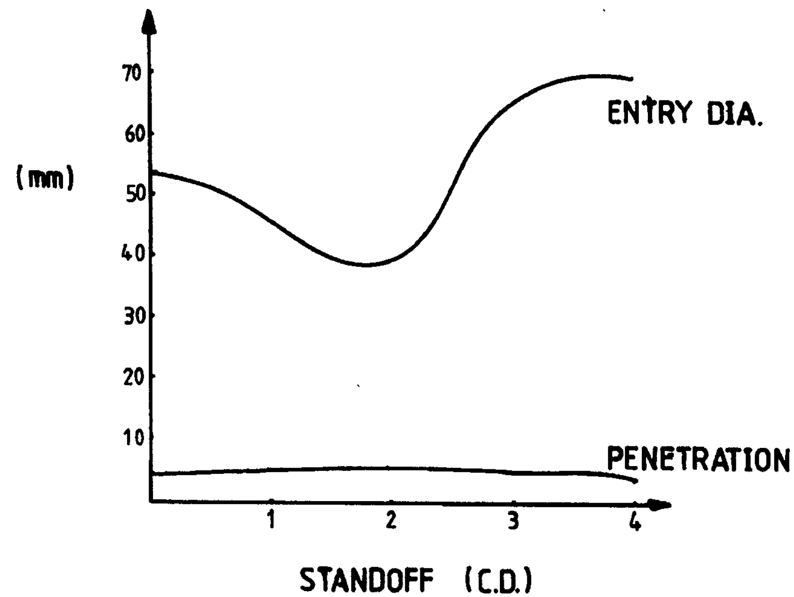




FLAT COPPER DISC (1·0mm thk)

STANDOFF (C.D.)	0	1	2	3	4
ENTRY DIAMETER (mm)	54	48	39	70	70
PENETRATION (mm)	4	5	5	3	3

J.T.V. = 2·9 mm/μs
CHARGE 38mm dia. WITH 1 C.D. HEAD HEIGHT.

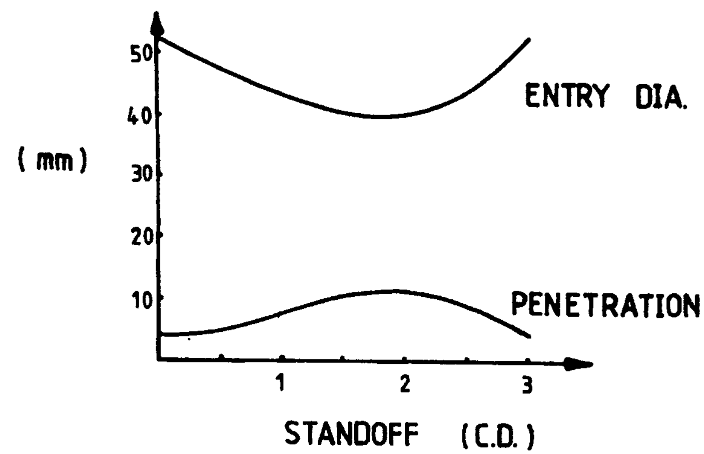


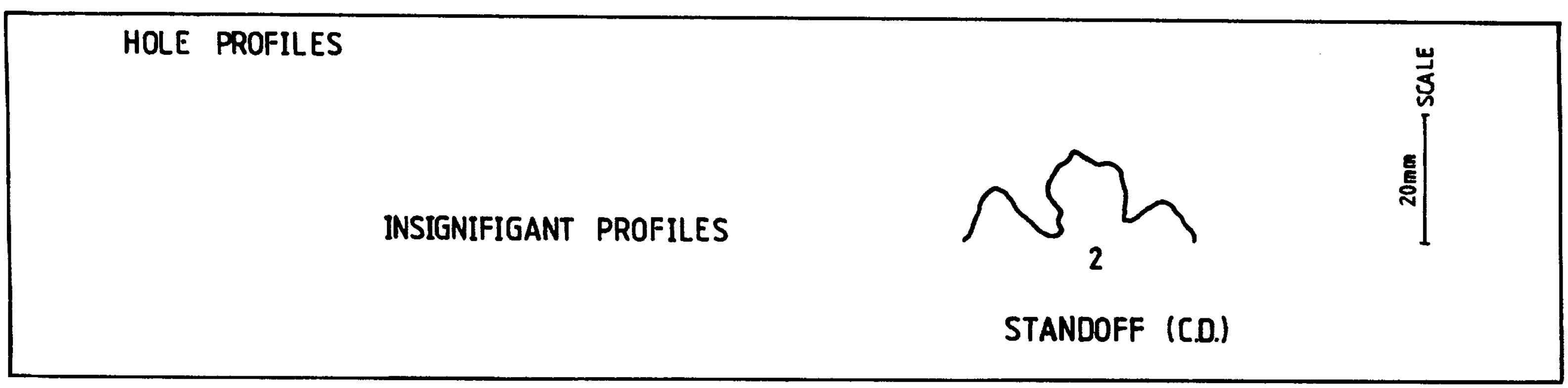
INSIGNIFICANT PENETRATION PROFILES

FLAT COPPER DISC (1·5mm thk)

STANDOFF (C.D.)	0	1	2	3
ENTRY DIAMETER (mm)	53	45	40	53
PENETRATION (mm)	4	6	12	4

J.T.V. = 2·0 mm/μs
CHARGE 38mm dia. WITH 1 C.D. HEAD HEIGHT.

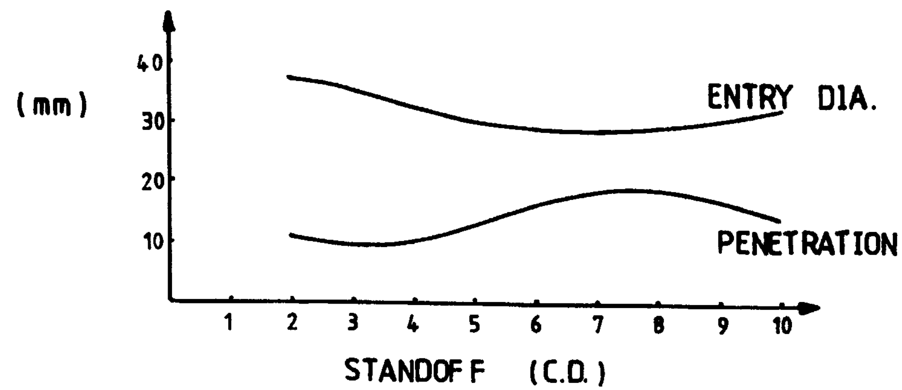


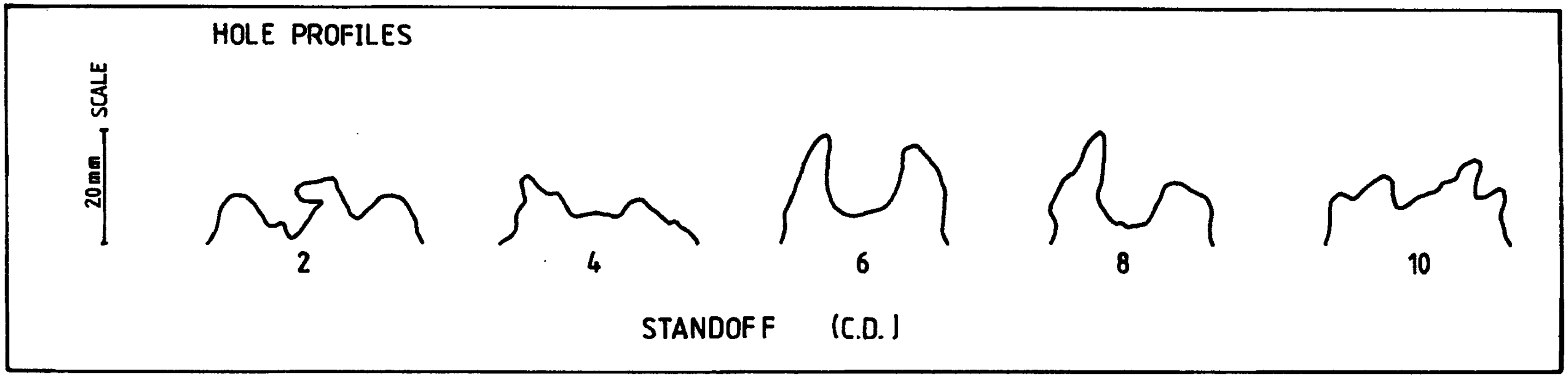


R 80 COPPER CAP

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	37	34	29	29	32
PENETRATION (mm)	11	10	18	20	14

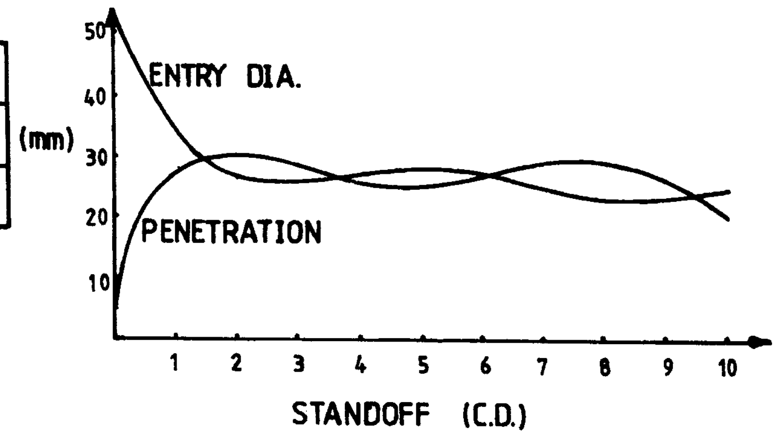
J.T.V = 2·9 mm/μs
CHARGE 38 mm dia. WITH 1 C.D. HEAD HEIGHT.



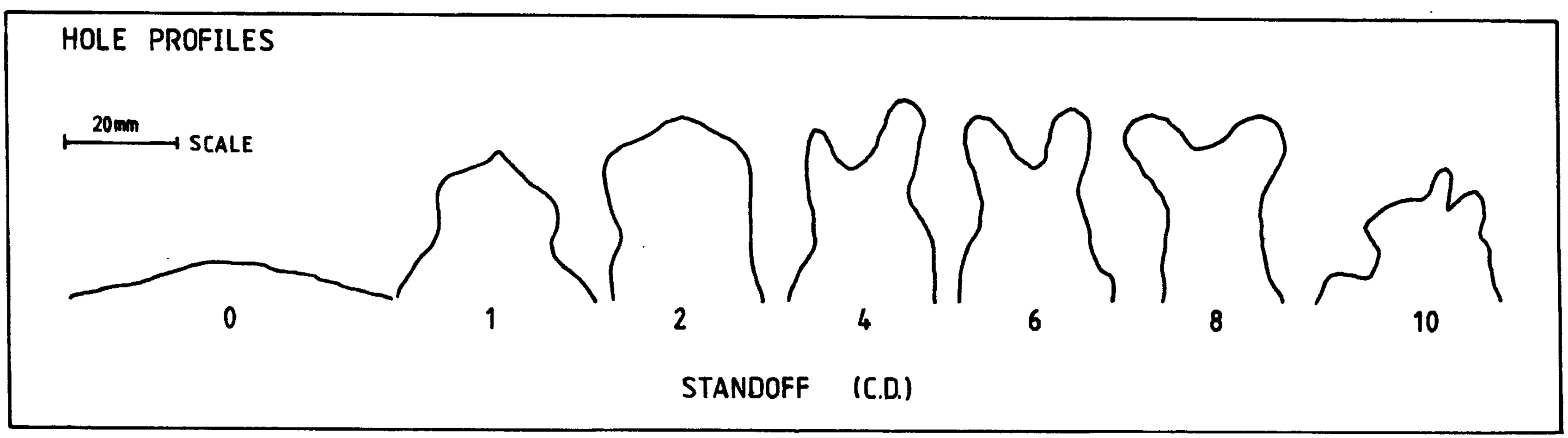


R 40 COPPER CAP

STANDOFF (C.D.)	0	1	2	4	6	8	10
ENTRY DIAMETER (mm)	53	36	26	27	28	23	25
PENETRATION	5	28	31	26	26	30	22



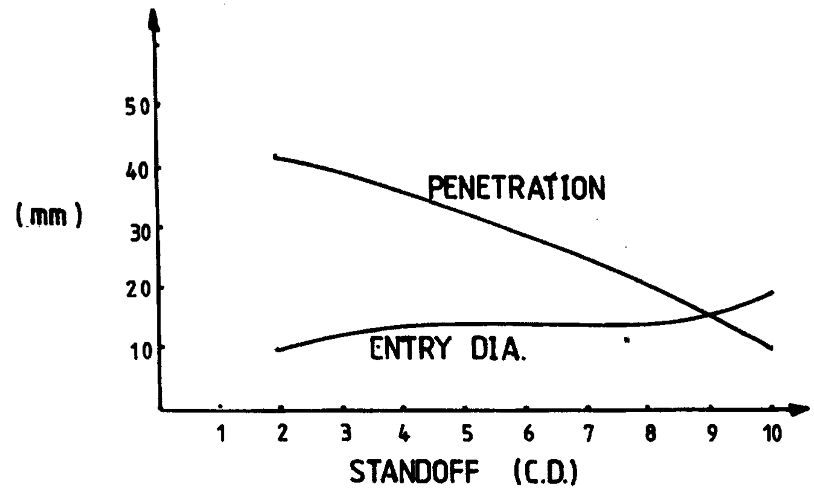
J.T.V. = 2·5 mm/μs
CHARGE 38 mm dia. WITH 1 C.D. HEAD HEIGHT.

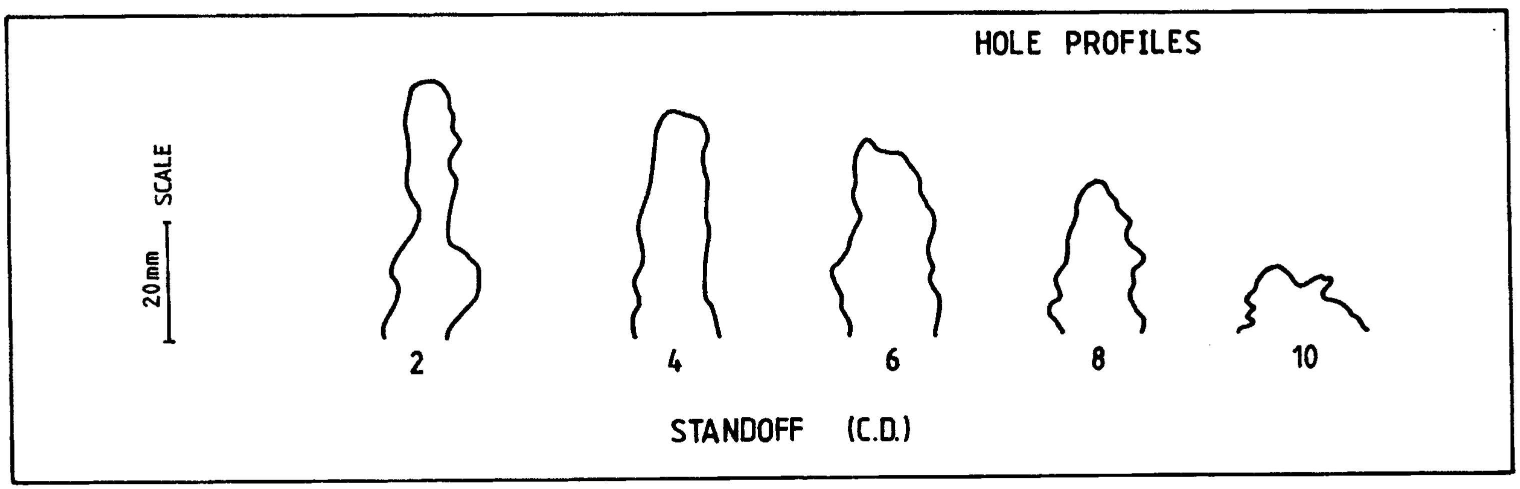


R 40 COPPER CAP (SEGMENTED)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	10	14	15	14	20
PENETRATION (mm)	42	36	31	22	10

J.T.V. = 1·9 mm/µs
CHARGE 38mm dia. WITH 1 C.D. HEAD HEIGHT.

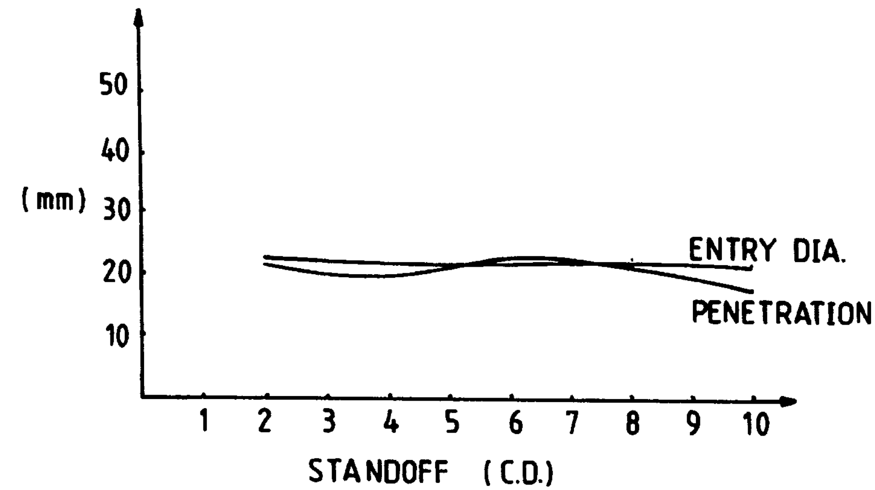


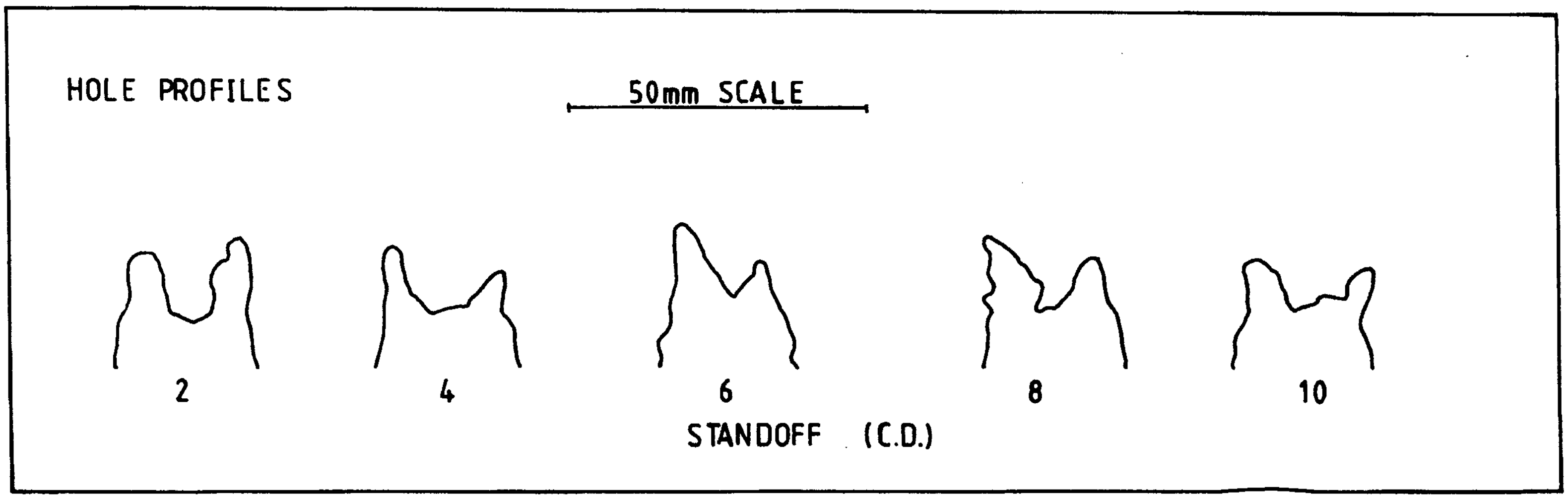


R40 × 1·0 mm COPPER (φ38mm)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	23	22	22	23	22
PENETRATION (mm)	22	20	23	22	18

J.T.V. = 2·05 mm/us
CHARGE FILLED TO 1/2 C.D. HEAD HEIGHT.
PERSPEX CASE.



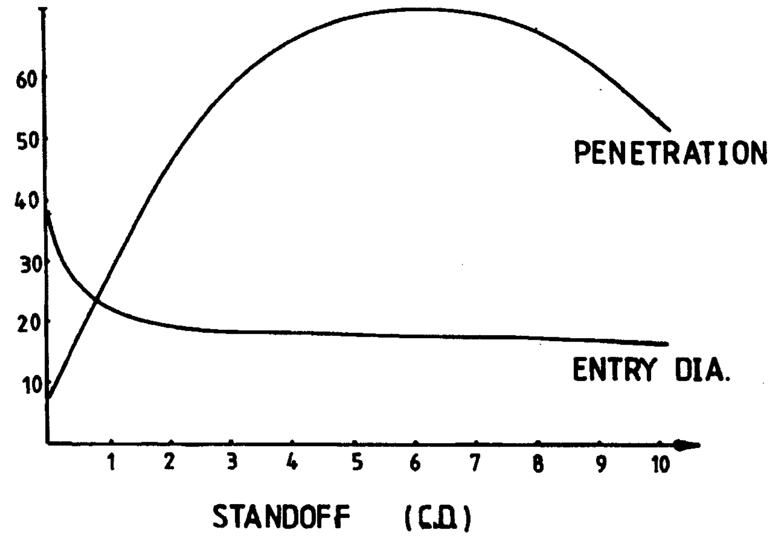


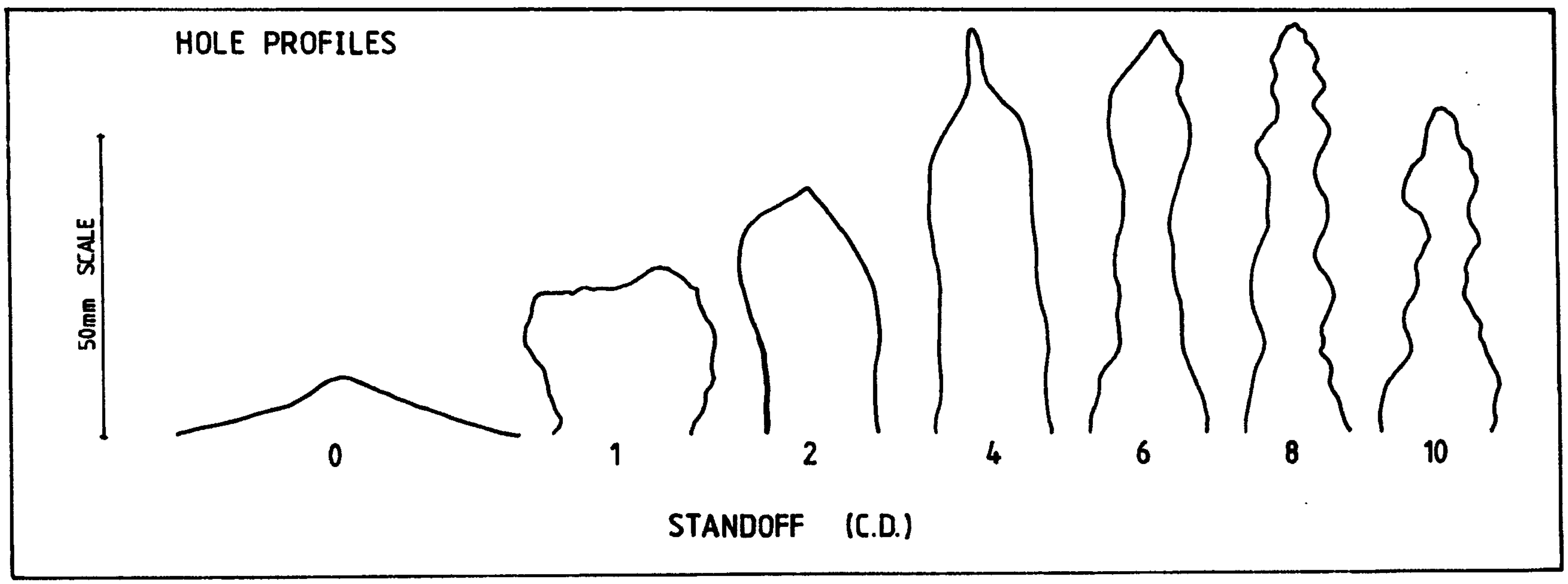
R 30 COPPER CAP (0·9mm thk)

STANDOFF (C.D.)	0	1	2	4	6	8	10
ENTRY DIAMETER (mm)	38	22	20	20	19	16	17
PENETRATION (mm)	8	27	40	68	66	68	53

(mm)

J.T.V. = 3·0 mm/μs
CHARGE 38mm dia. WITH 1 C.D. HEAD HEIGHT.

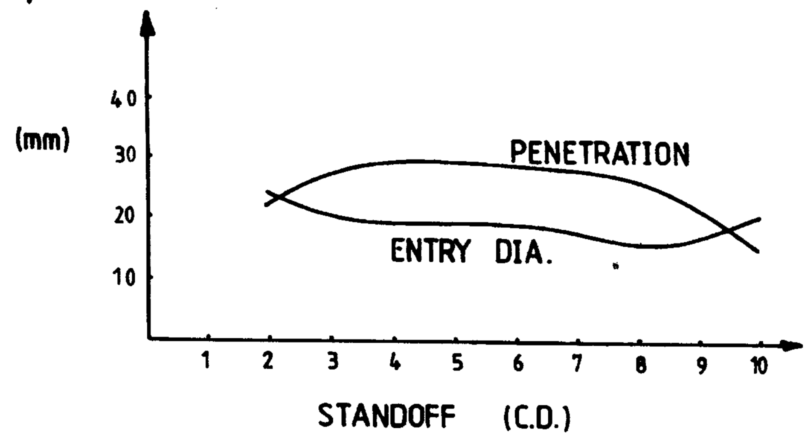


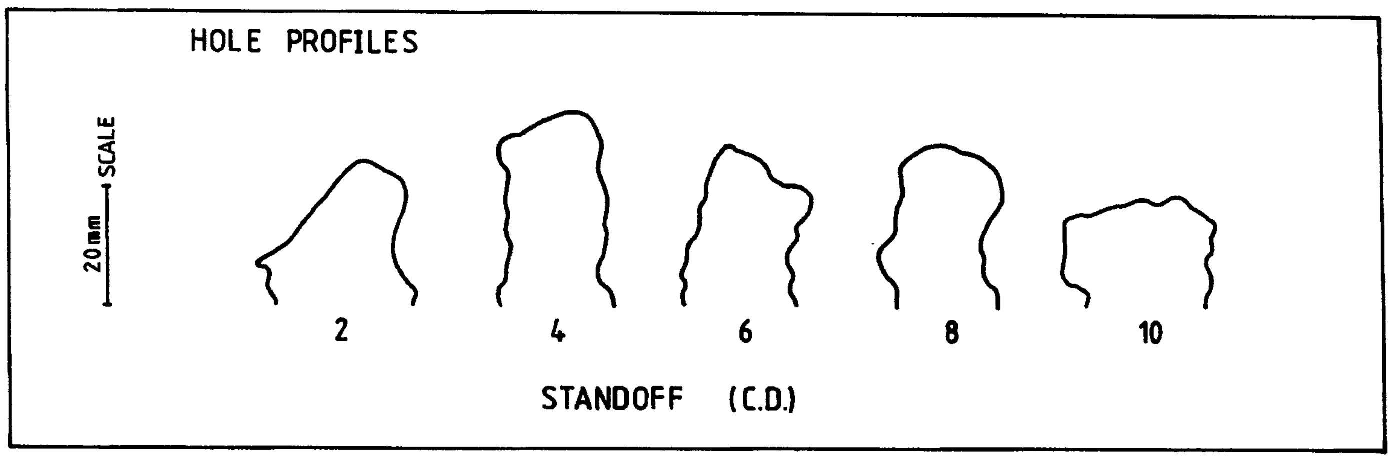


R 30 COPPER CAP (19·0mm head height)

STANDOFF (C.D.)	0	2	4	6	8	10
ENTRY DIAMETER (mm)	–	24	19	19	16	20
PENETRATION (mm)	–	22	30	26	27	16

J.T.V. = 2·0 mm/μs
CHARGE 38 mm dia.

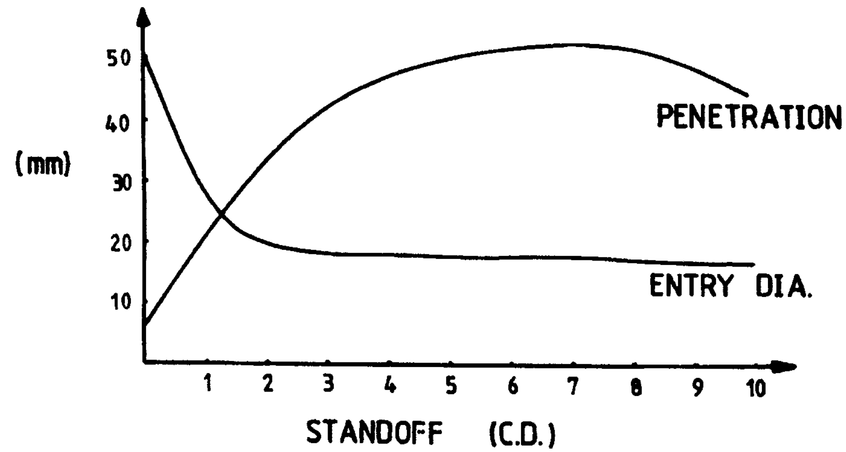


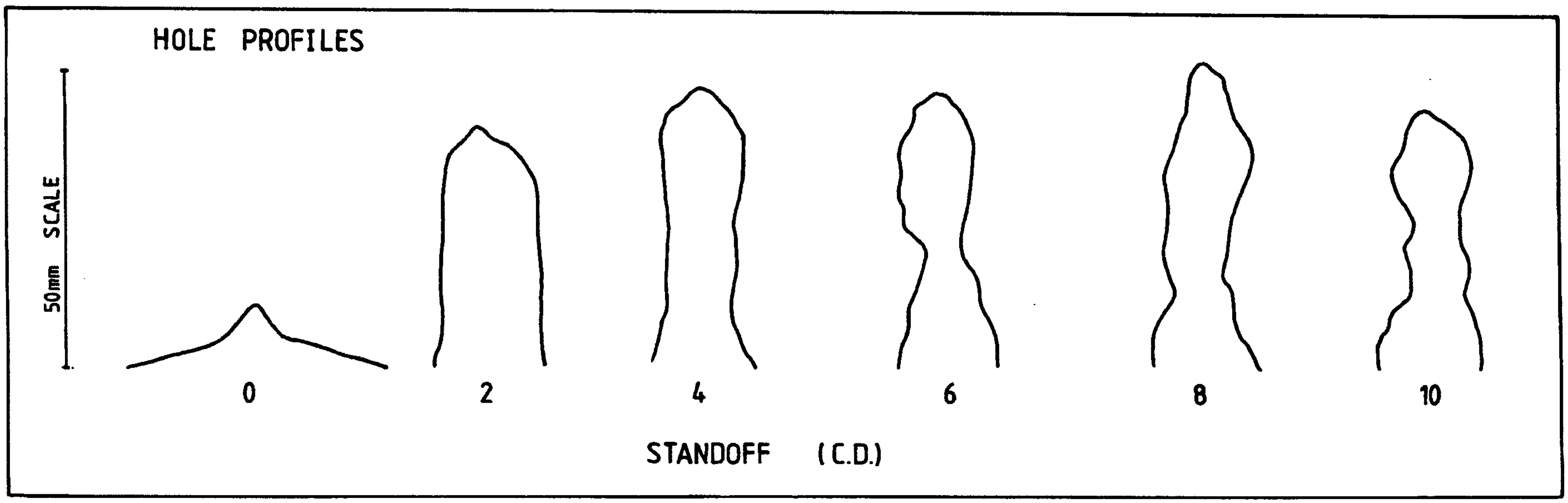


R 30 COPPER CAP (1·6mm thk)

STANDOFF (C.D.)	0	2	4	6	8	10
ENTRY DIAMETER (mm)	50	20	18	18	18	17
PENETRATION (mm)	6	35	46	46	55	45

J.T.V. = 2·1 mm/μs
CHARGE 38mm dia. WITH 1 C.D. HEAD HEIGHT.

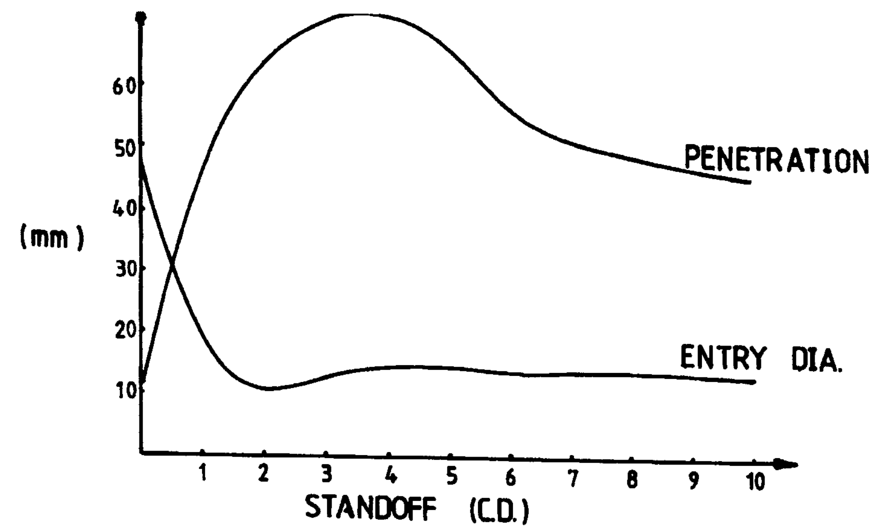


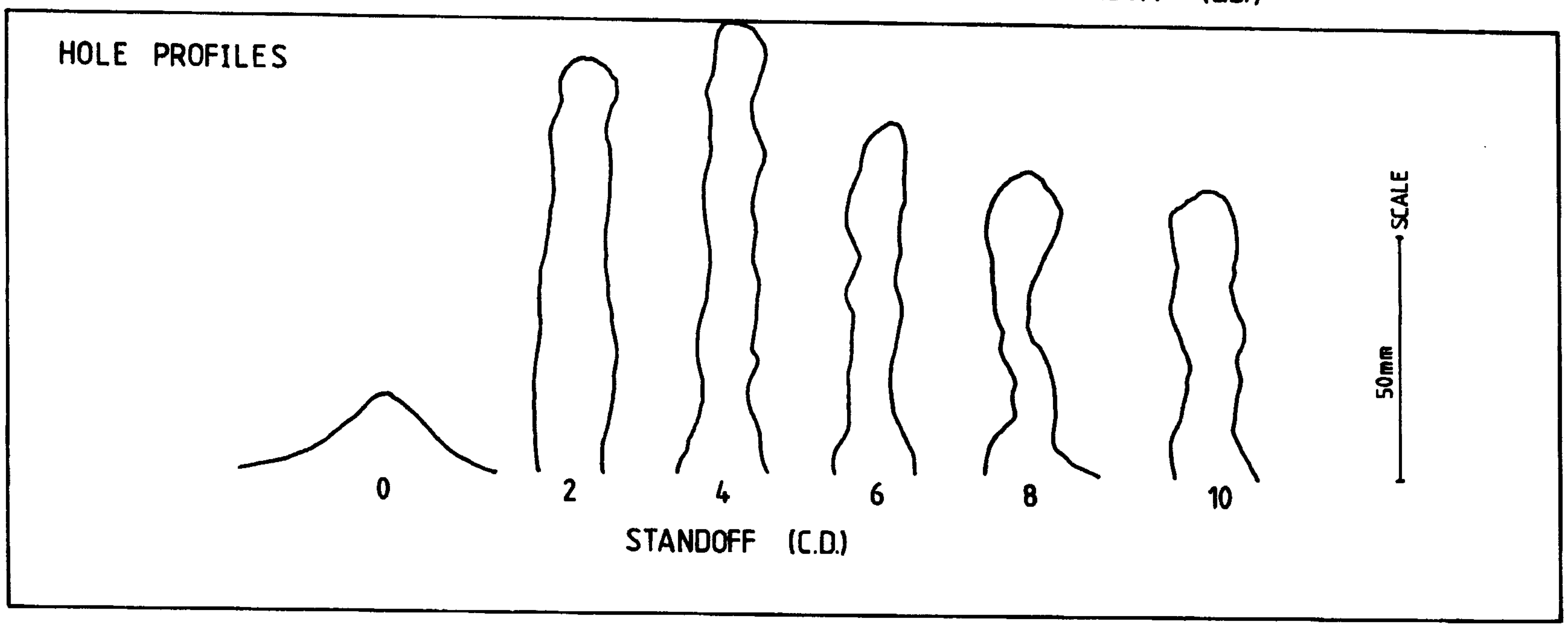


R 25 COPPER CAP

STANDOFF (C.D.)	0	2	4	6	8	10
ENTRY DIAMETER (mm)	48	10	15	14	15	13
PENETRATION (mm)	12	64	74	57	49	46

J.T.V. = 2·3 mm/µs
CHARGE 38 mm dia. WITH 1 C.D. HEAD HEIGHT.

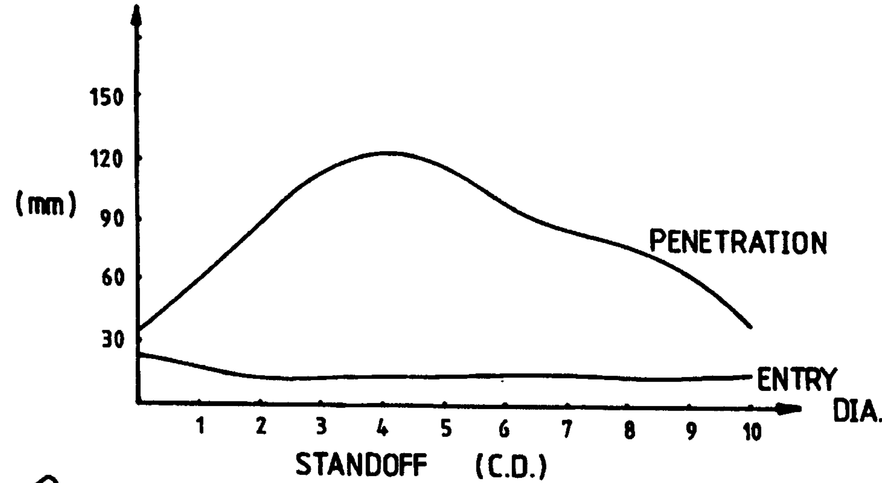


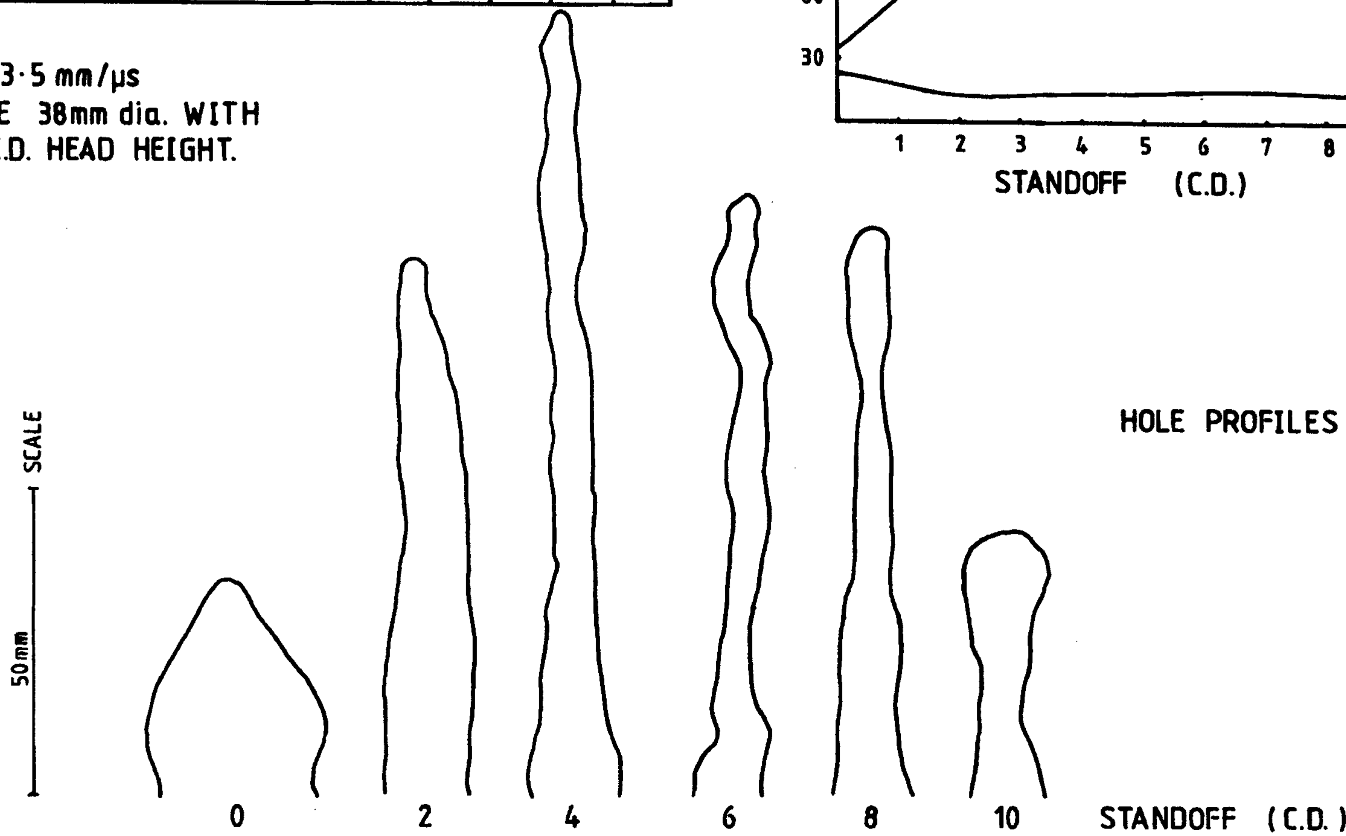


COPPER HEMISPHERE

STANDOFF (C.D.)	0	2	4	6	8	10
ENTRY DIAMETER (mm)	25	14	15	11	13	15
PENETRATION (mm)	35	88	130	94	91	40

J.T.V. = 3·5 mm/μs
CHARGE 38mm dia. WITH
1 C.D. HEAD HEIGHT.

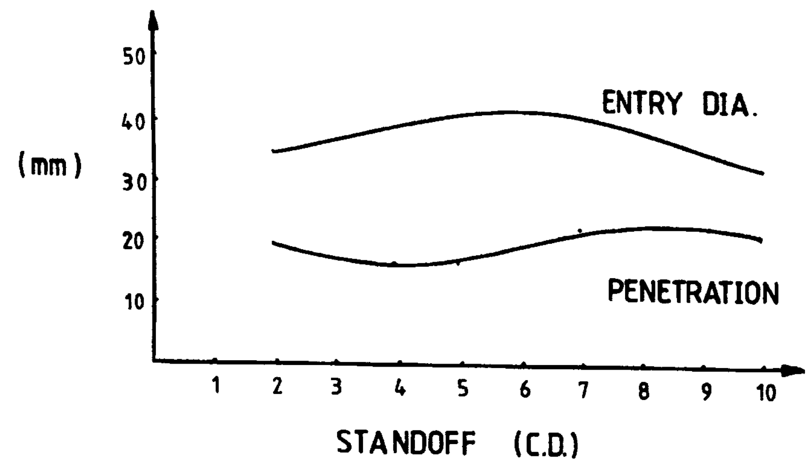


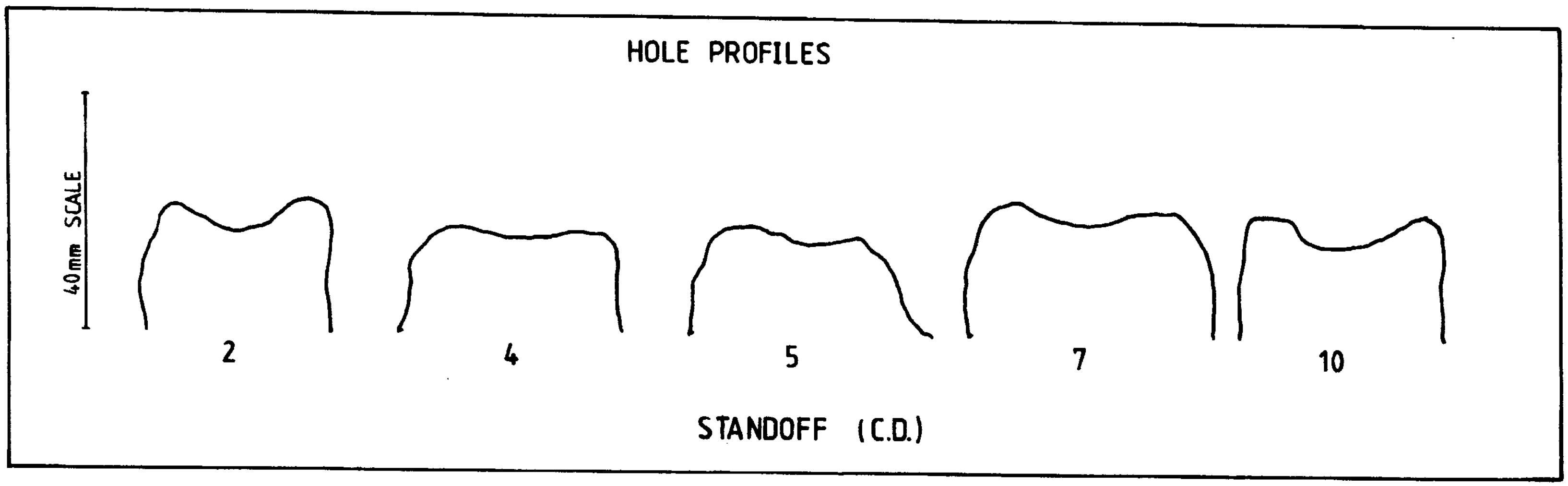


R 60 COPPER CAP (Φ60mm)

STANDOFF (C.D.)	2	4	5	7	10
ENTRY DIAMETER (mm)	35	38	41·5	41	33
PENETRATION (mm)	20	17	17	23	21

CHARGE FILLED TO 1/4 C.D. HEAD HEIGHT.
J.T.V. = 1·4 mm/μs



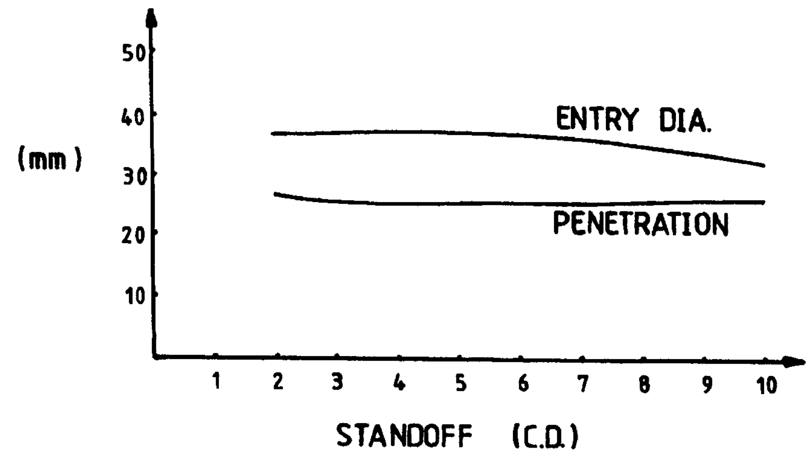


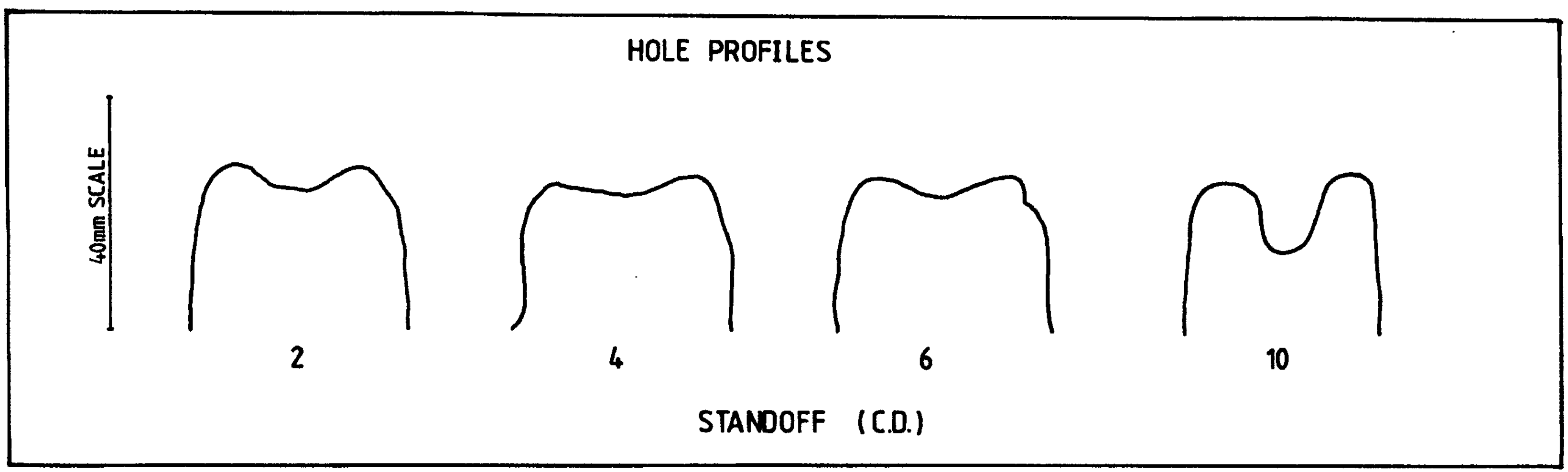
R 60 COPPER CAP (Φ60mm)

STANDOFF (C.D.)	2	4	6	10
ENTRY DIAMETER (mm)	37	37	37	32·5
PENETRATION (mm)	27	25	26	26

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT.

J.T.V. = 1·6 mm/μs

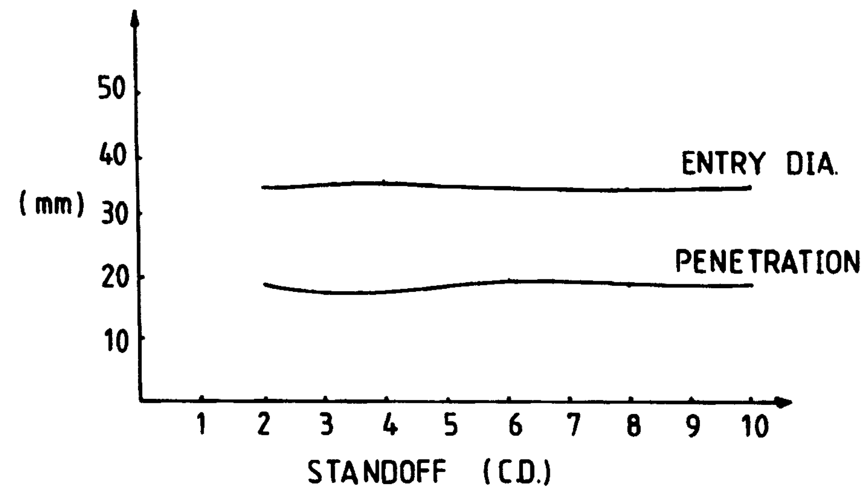


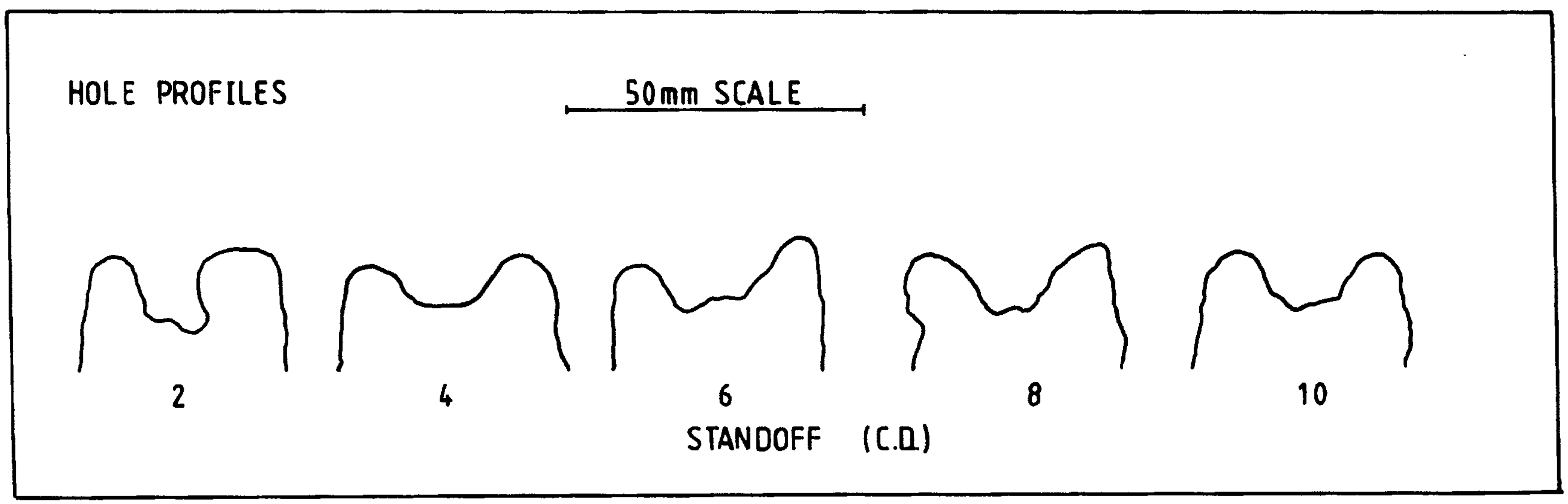


R60 × 2·0 mm COPPER (Φ60mm)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	35	36	35	35	35
PENETRATION (mm)	19	18	20	19	19

J.T.V. = 1·56 mm/us
CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT.
PERSPEX CASE.

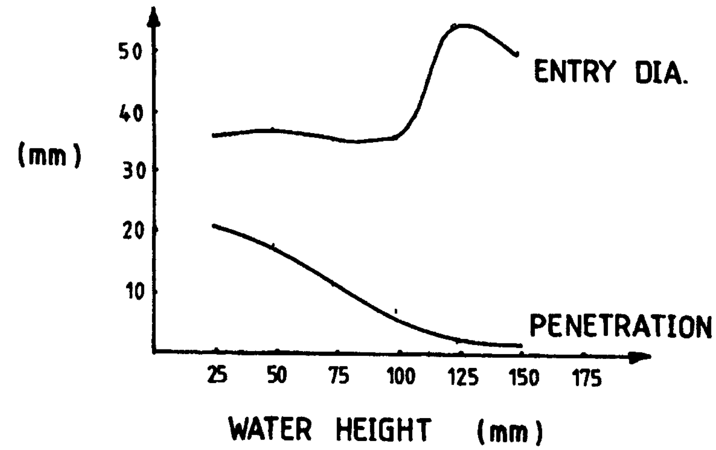


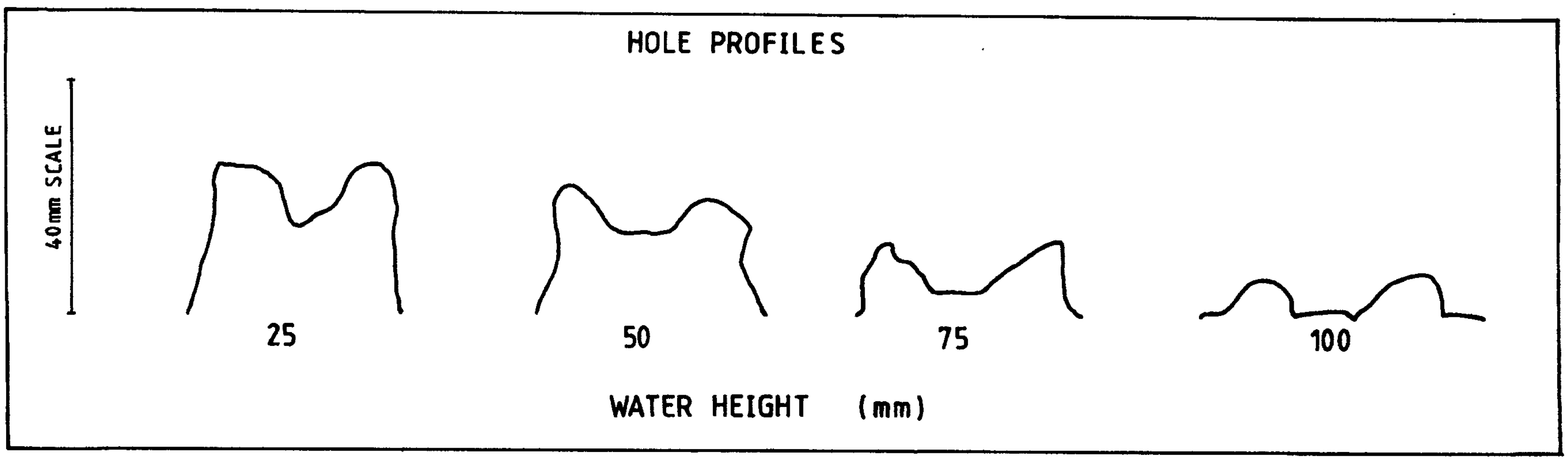


R 60 COPPER CAP (Ø60mm)

WATER HEIGHT (mm)	25	50	75	100	125	150
ENTRY DIAMETER (mm)	36	37	35	36	55	50
PENETRATION (mm)	21	18	11	7	2	2

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT.
STANDOFF USED 4 C.D.

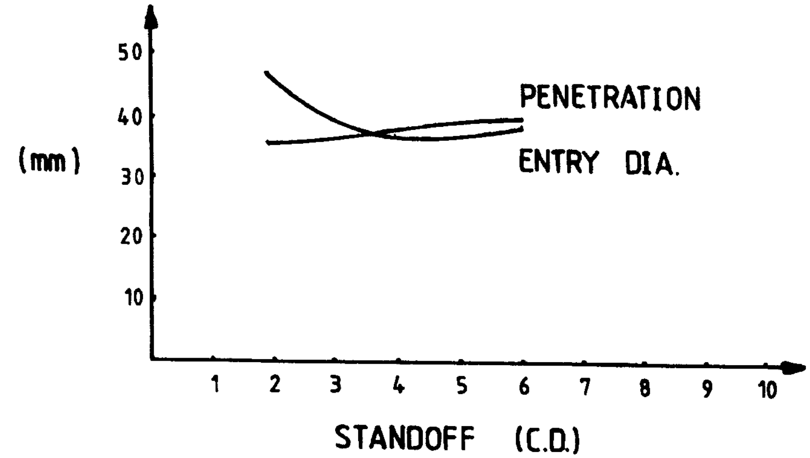


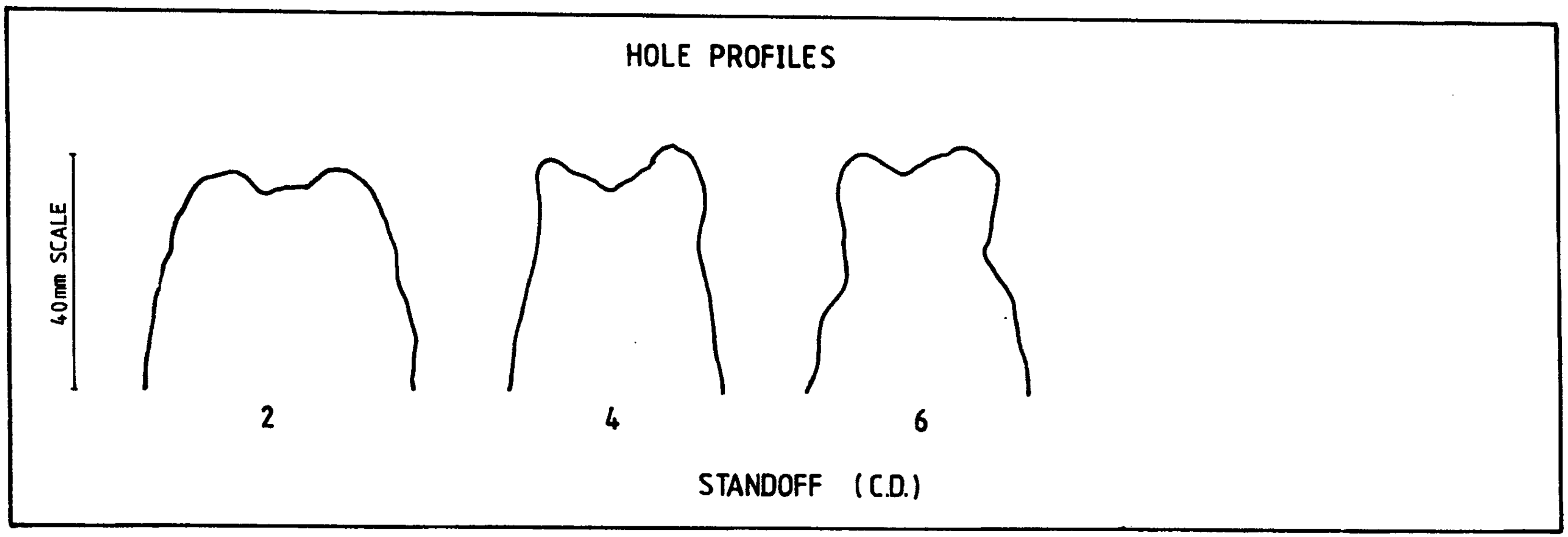


R 60 COPPER CAP (ϕ60mm)

STANDOFF (C.D.)	2	4	6	
ENTRY DIAMETER (mm)	47	37	38	
PENETRATION (mm)	36	38	40	

CHARGE FILLED TO 2/3 C.D HEAD HEIGHT.
J.T.V. = 2·1 mm/µs





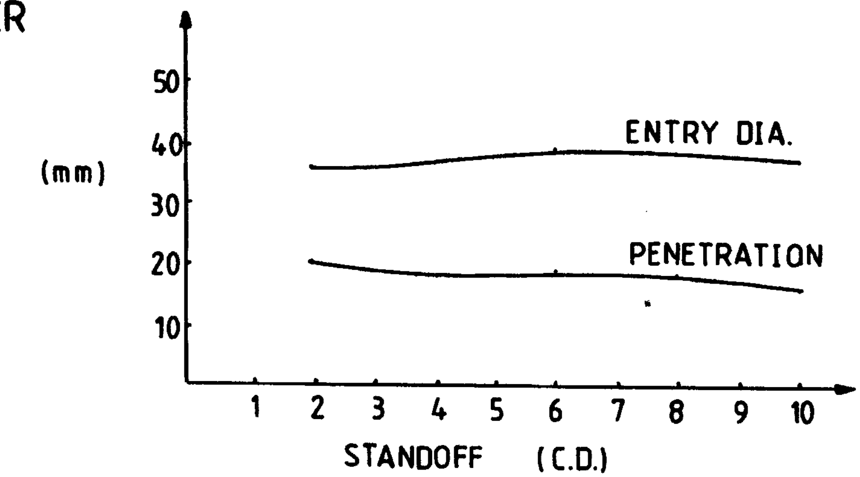
R 60 x Φ60mm x 2mm Cu + 1/16" RUBBER

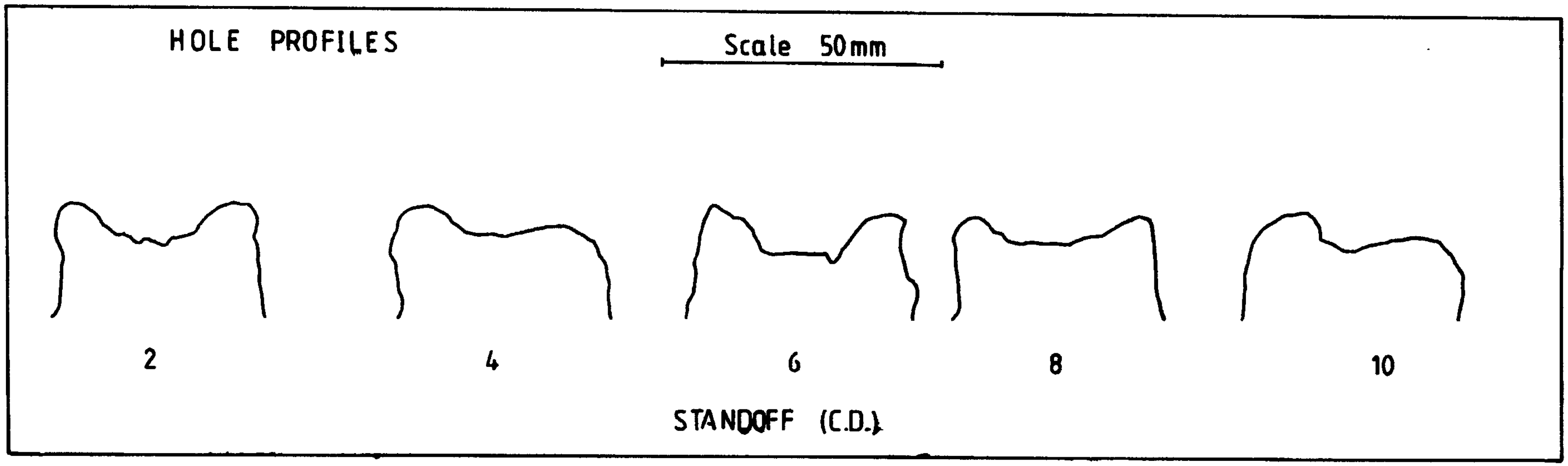
STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	36	37	39	38	37
PENETRATION (mm)	20	18	19	18	16

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 1·44 mm/μs



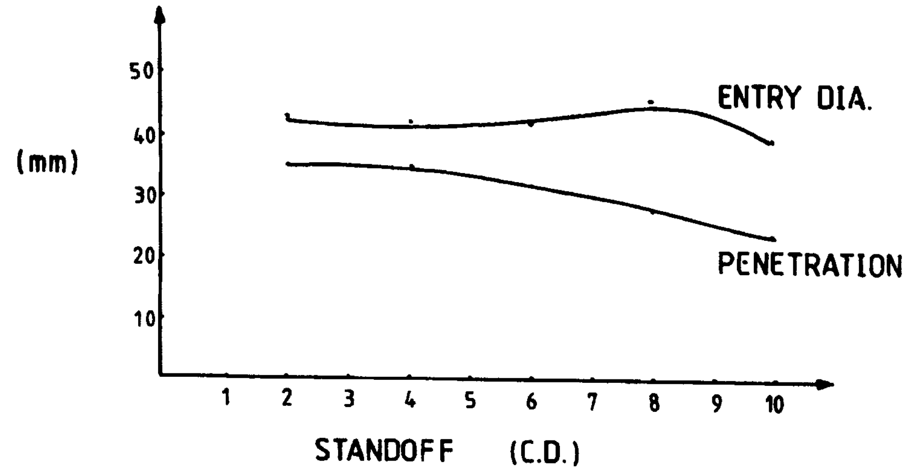


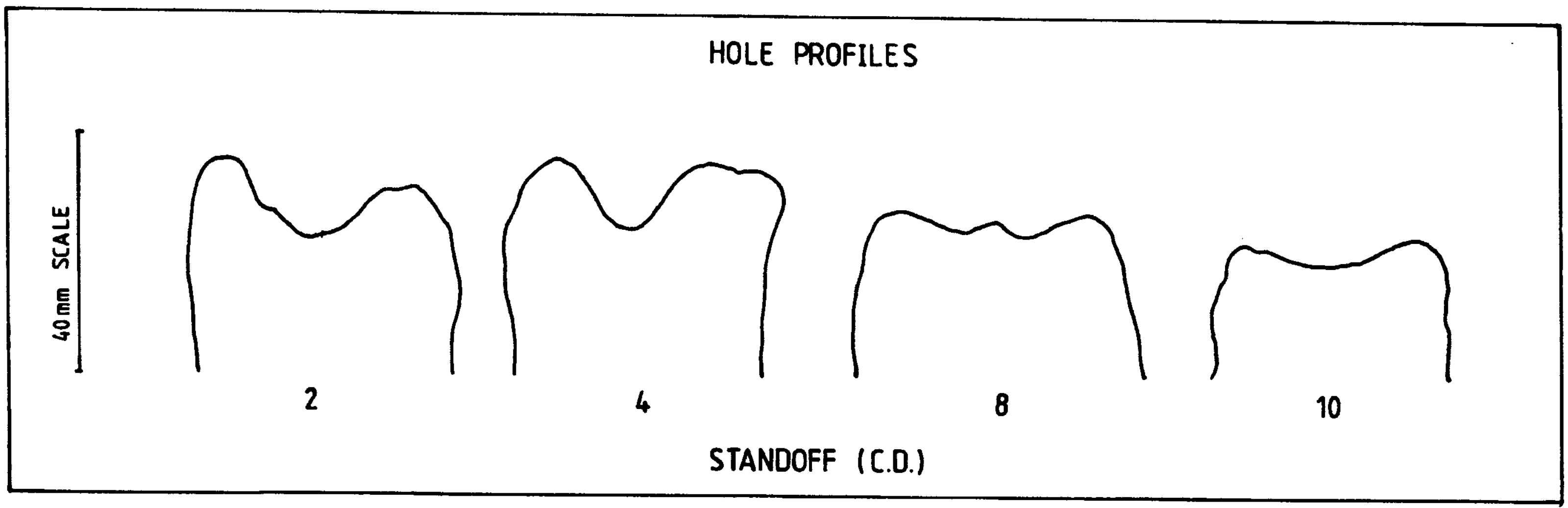
R 80 COPPER CAP (ϕ 80 mm)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	43	42	42	46	39
PENETRATION (mm)	35	35	32	28	24

CHARGE FILLED TO 1/4 C.D. HEAD HEIGHT.

J.T.V. = 1·7 mm/μs

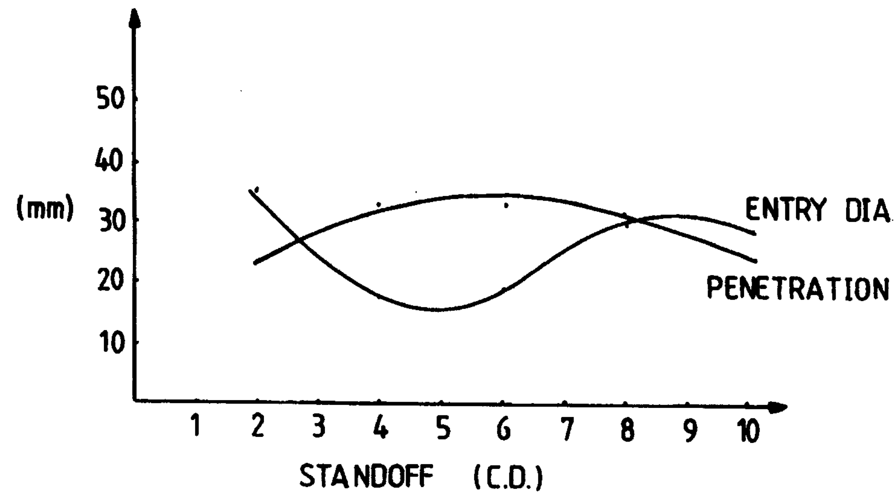


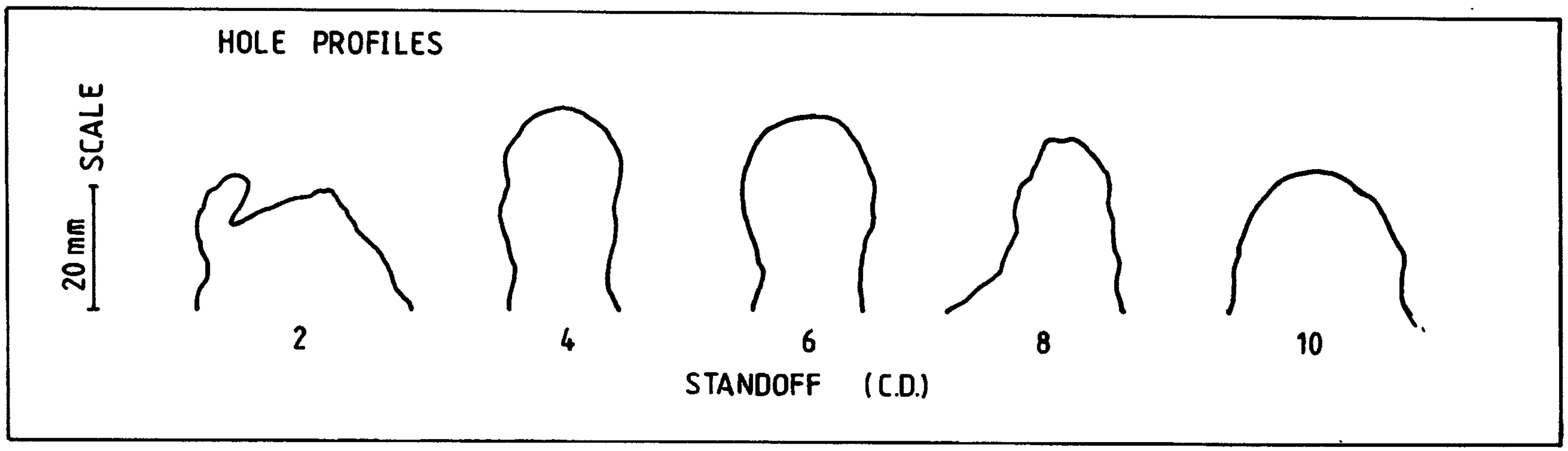


ϕ40 Cu CONTOUR LINER (2·0-1·0)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	35	18	19	32	29
PENETRATION (mm)	23	33	33	30	24

J.T.V. = 2·0 mm/μs
CHARGE FILLED TO 1 C.D. HEAD HEIGHT.

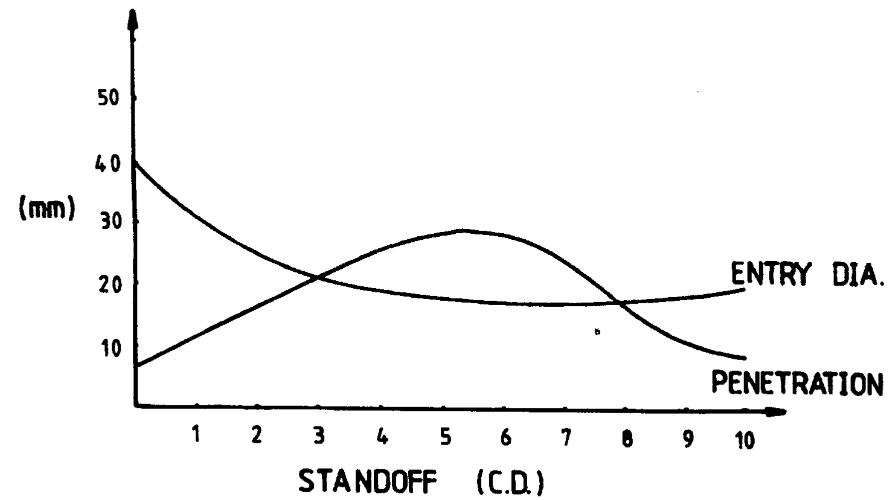


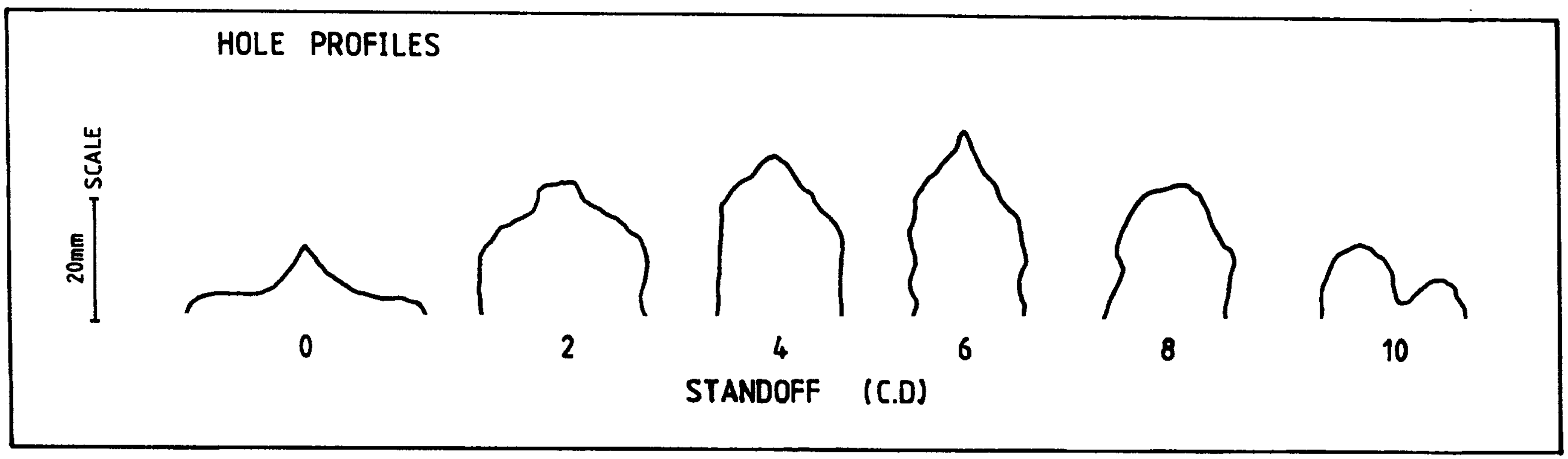


140° ALUMINIUM LINER

STANDOFF (C.D.)	0	2	4	6	8	10
ENTRY DIAMETER (mm)	40	26	20	19	18	20
PENETRATION (mm)	7	19	25	30	18	9

J.T.V. = 4·9 mm/µs
CHARGE 38mm dia WITH 1 C.D. HEAD HEIGHT.

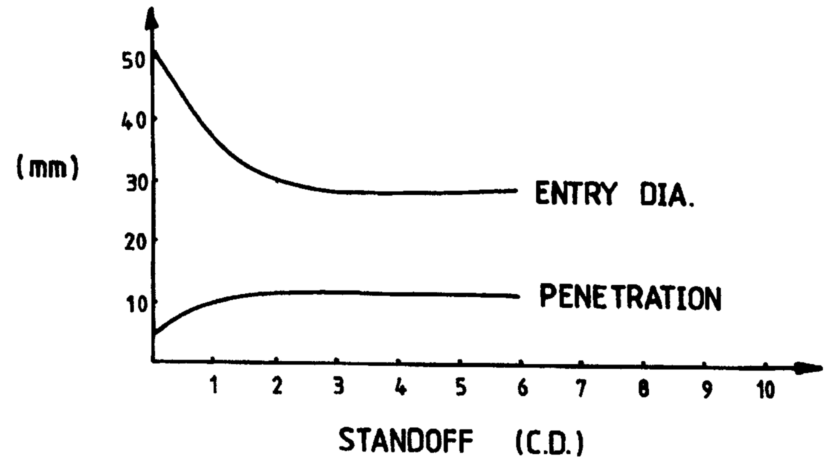


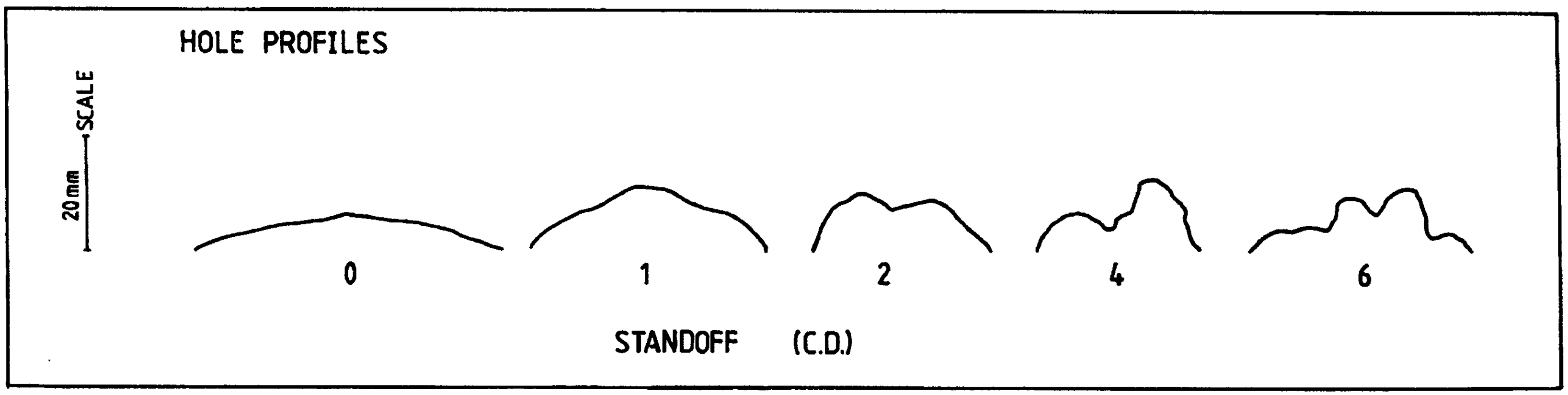


R 40 ALUMINIUM CAP

STANDOFF (C.D.)	0	1	2	4	6
ENTRY DIAMETER (mm)	51	40	30	29	30
PENETRATION (mm)	5	10	10	12	11

J.T.V. = 5·1 mm/μs
CHARGE 38mm dia. WITH 1C.D. HEAD HEIGHT.

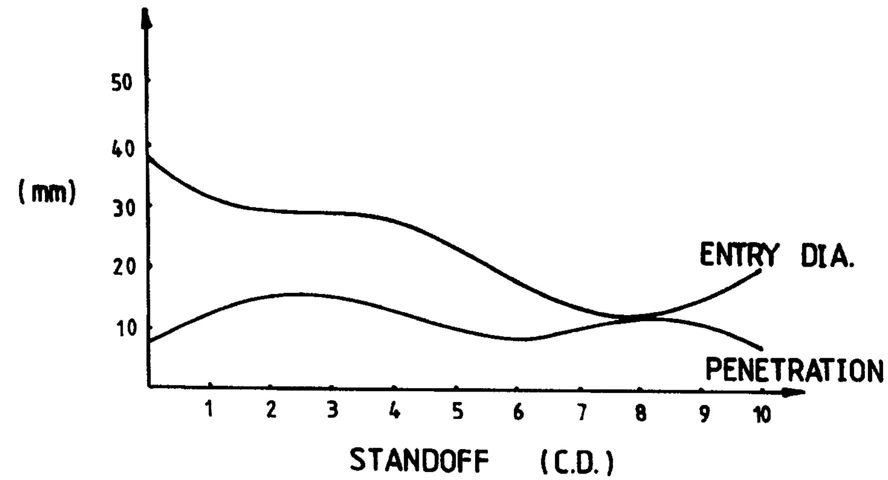


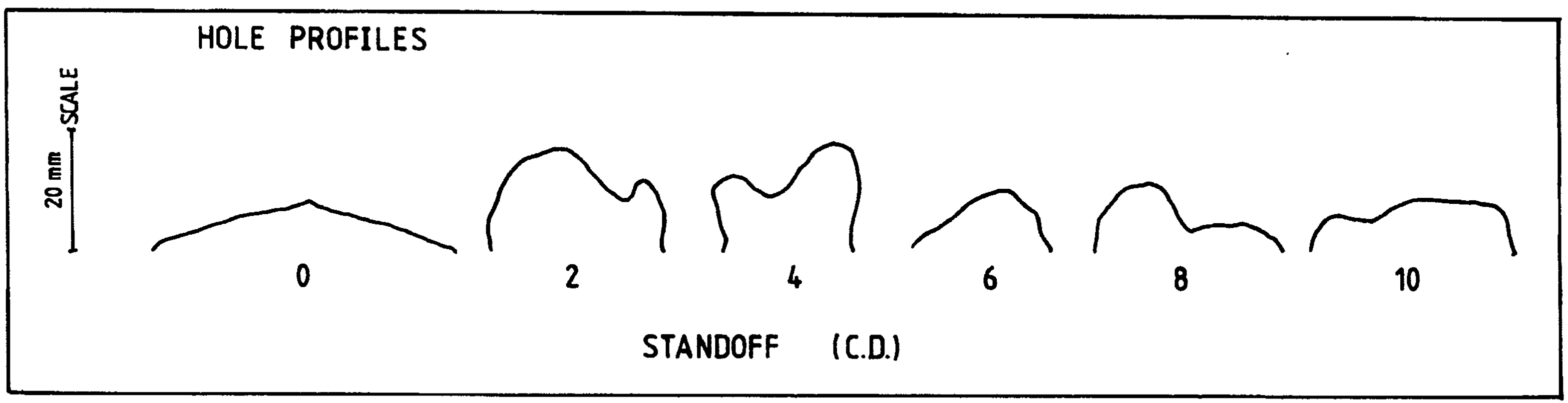


R 30 ALUMINIUM CAP

STANDOFF (C.D.)	0	2	4	6	8	10
ENTRY DIAMETER (mm)	38	28	28	20	12	20
PENETRATION (mm)	7	17	15	8	12	7

J.T.V. = 4·5 mm/μs
CHARGE 38 mm dia. WITH 1 C.D. HEAD HEIGHT.

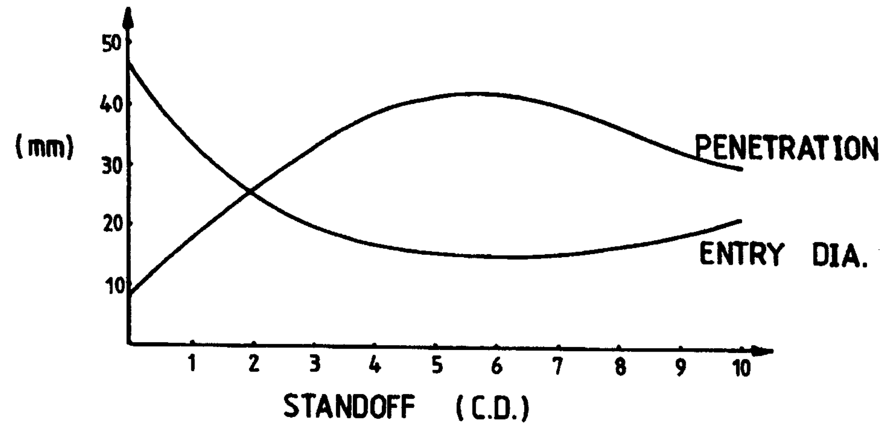


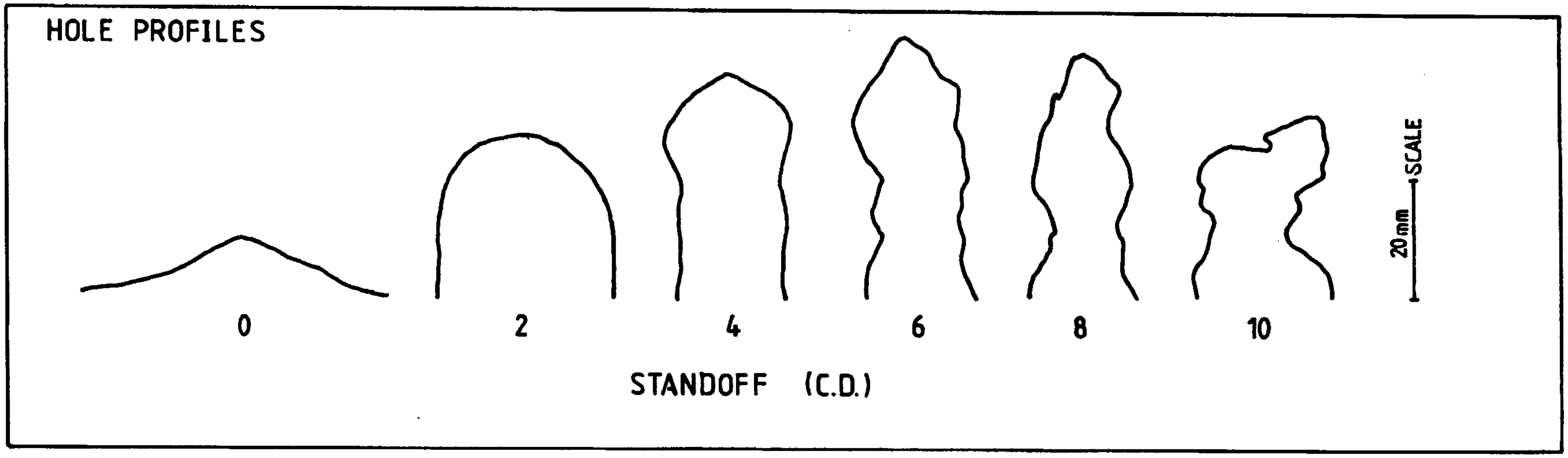


R 25 ALUMINIUM CAP

STANDOFF (C.D.)	0	2	4	6	8	10
ENTRY DIAMETER (mm)	47	26	18	16	17	21
PENETRATION (mm)	8	26	37	43	37	31

J.T.V. = 4·5 mm/μs
CHARGE 38mm dia WITH 1 C.D. HEAD HEIGHT.

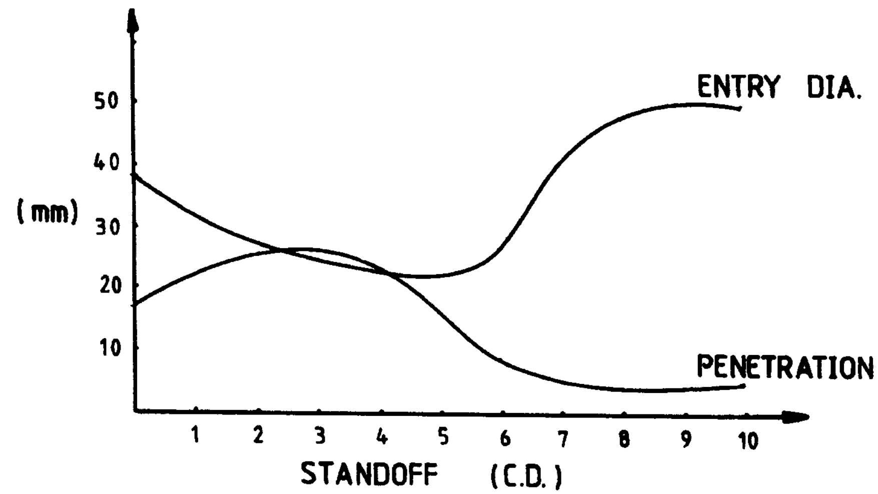


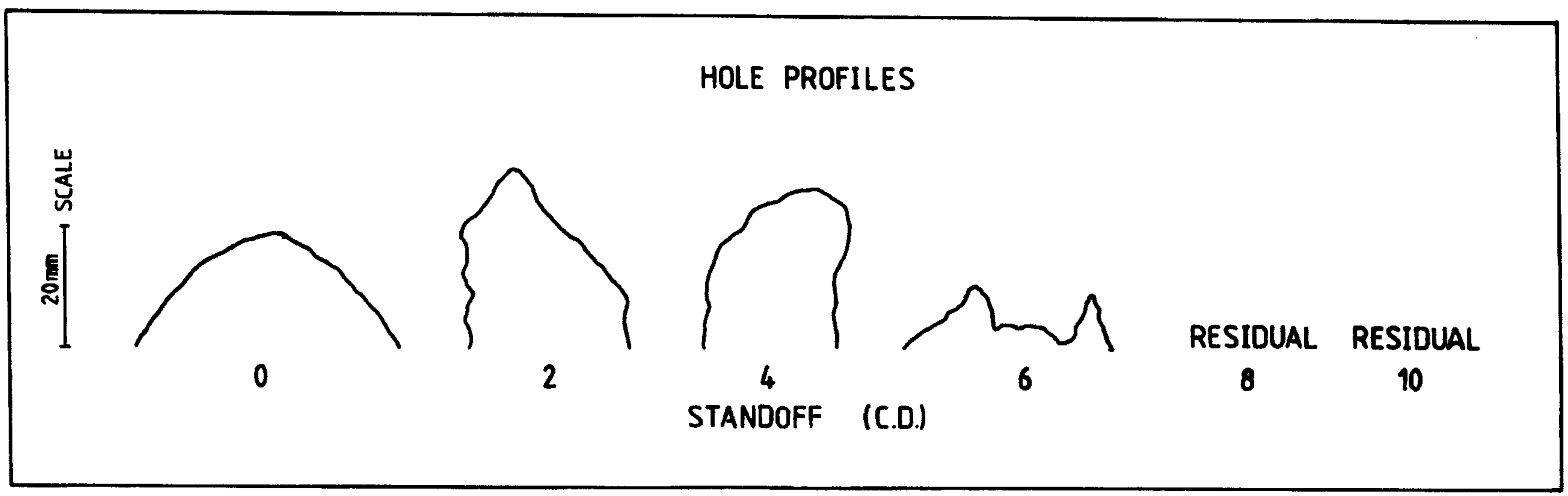


ALUMINIUM HEMISPHERE

STANDOFF (C.D.)	0	2	4	6	8	10
ENTRY DIAMETER (mm)	38	28	24	27	50	50
PENETRATION (mm)	17	26	26	9	5	5

J.T.V. = 5·4 mm/μs
CHARGE 38mm dia. WITH 1 C.D. HEAD HEIGHT.

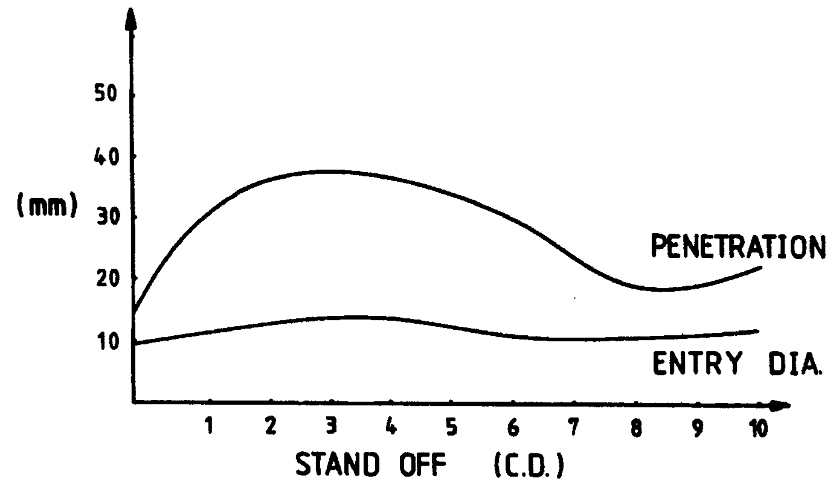


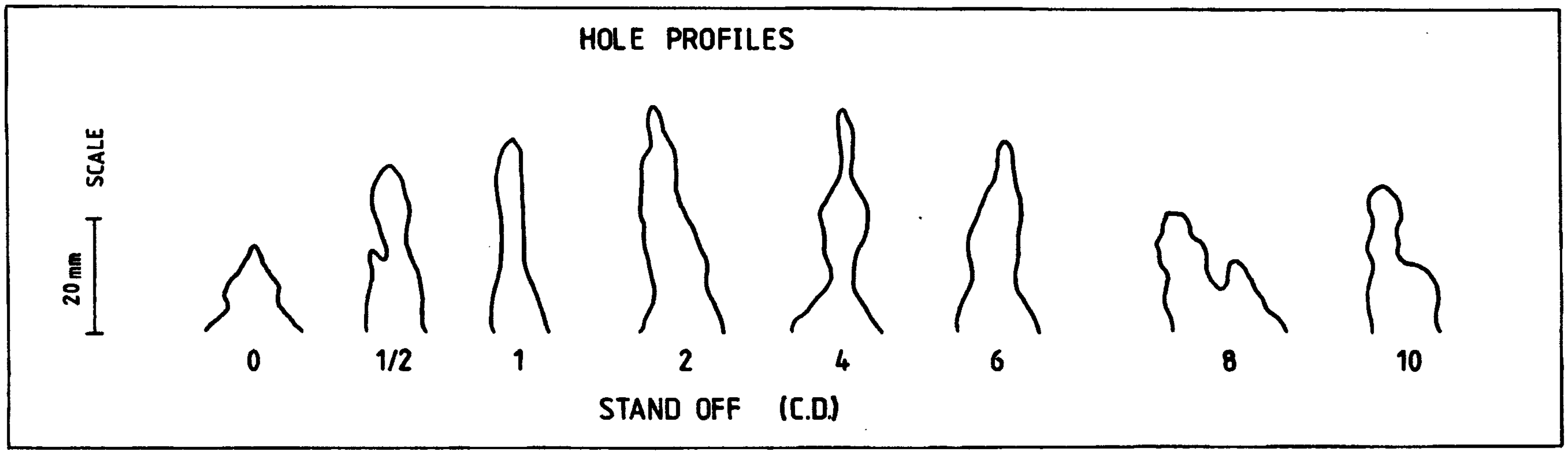


Mk 2 Mod.1 FOCAL POINT

STAND OFF (C.D.)	0	1/2	1	2	4	6	8	10
ENTRY DIAMETER (mm)	10	10	11	13	15	12	12	12
PENETRATION (mm)	15	30	33	38	38	33	20	24

J.T.V. = 5·0 mm/μs

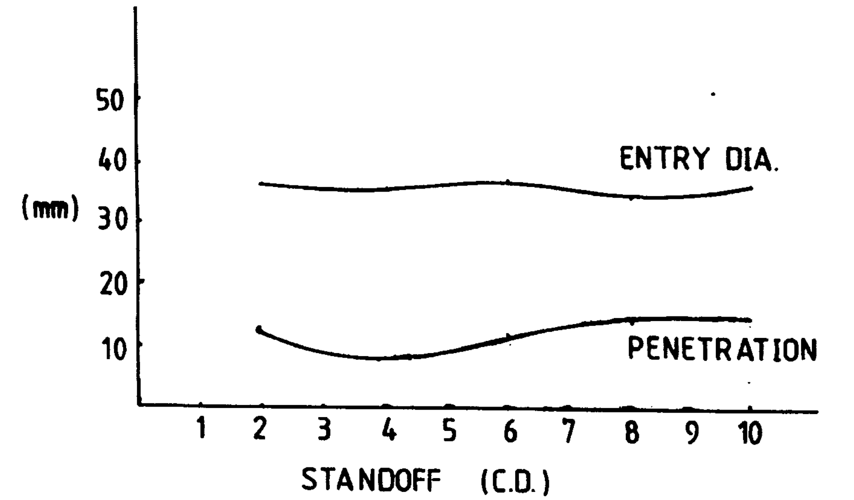


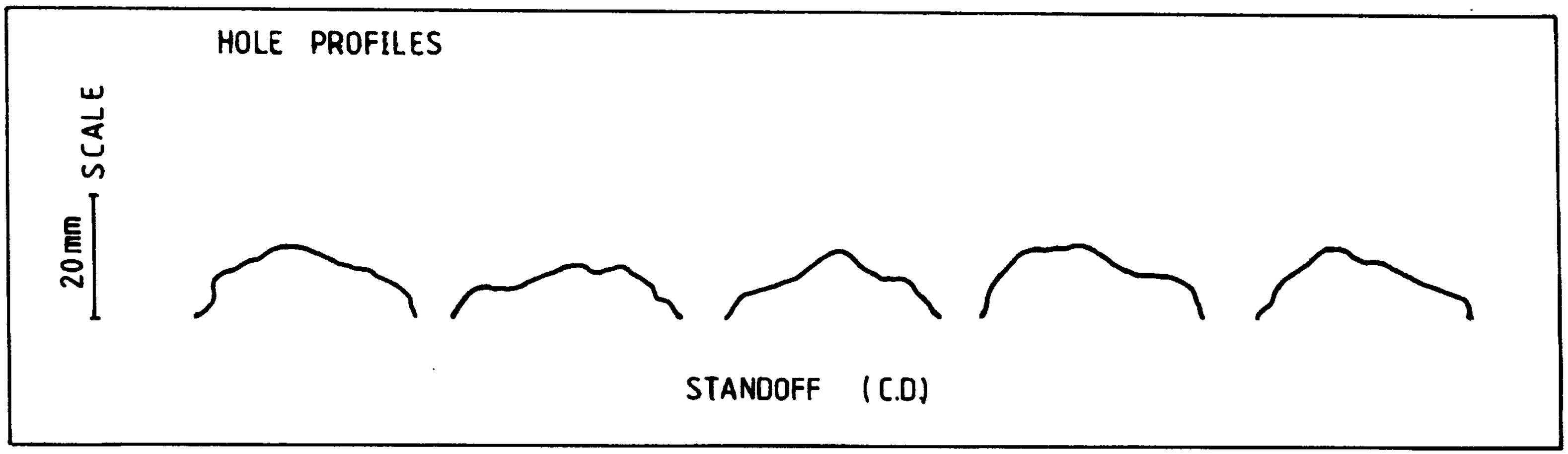


Φ40 L.C.S. CONTOUR LINER (2·0-1·5)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	36	35	37	34	36
PENETRATION (mm)	12	8	12	14	14

J.T.V. = 1·7 mm/μs
CHARGE FILLED TO 1 C.D. HEAD HEIGHT.

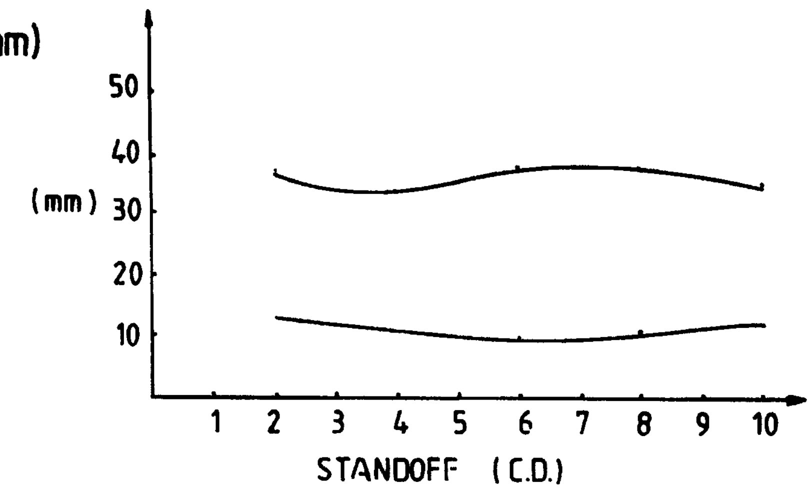


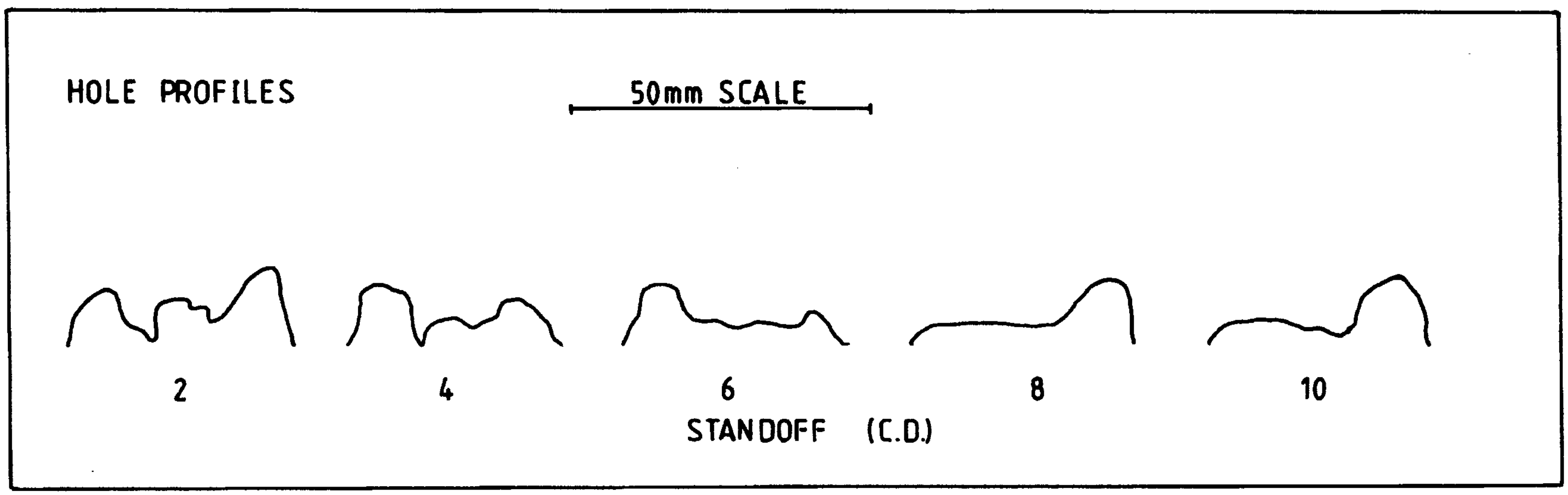


R40 × 1·95mm LOW CARBON STEEL (Ø38mm)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	37	34	38	38	35
PENETRATION (mm)	13	11	10	11	12

J.T.V = 1·91 mm/us
CHARGE FILLED TO 1 C.D. HEAD HEIGHT.



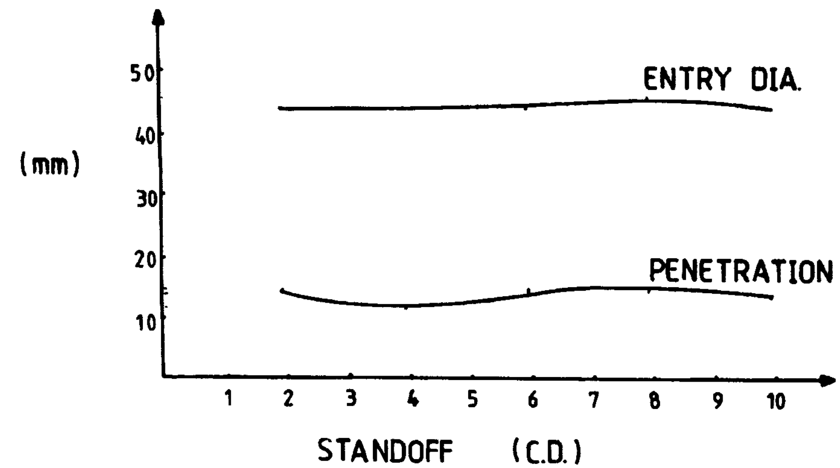


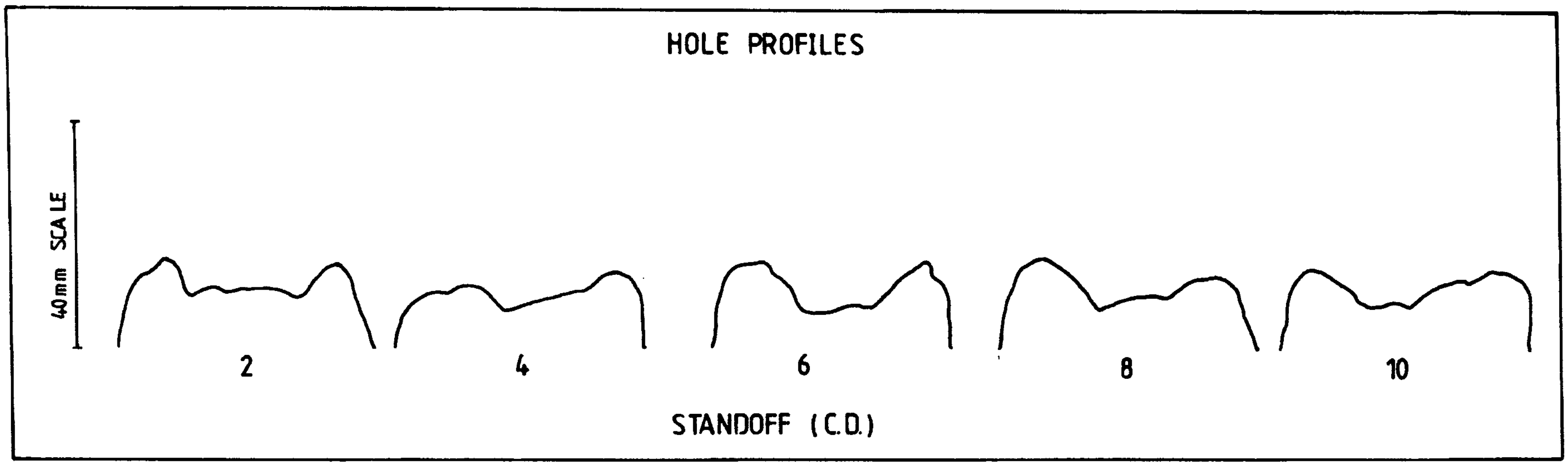
R 60 LOW CARBON STEEL CAP (Φ60mm)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	44	44	44	46	44
PENETRATION (mm)	15	12	15	15	14

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT.

J.T.V. = 1·8 mm/μs

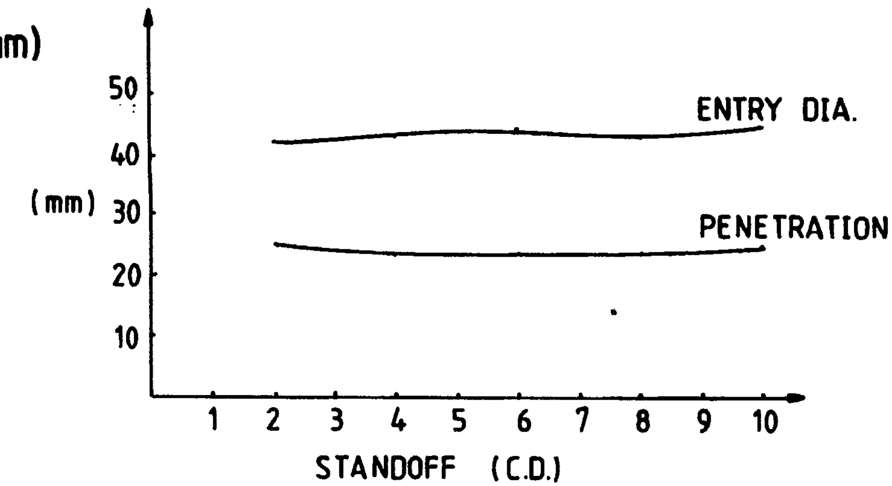


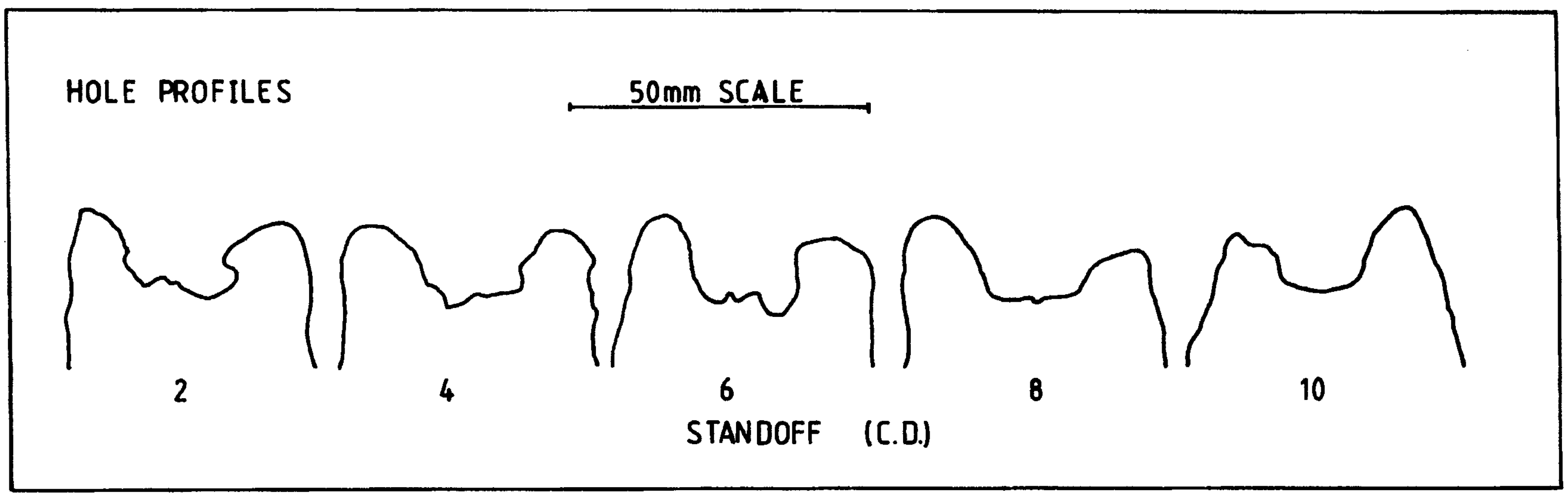


R60 x 1·95mm LOW CARBON STEEL (Ø60mm)

STANDOFF (C.D.).	2	4	6	8	10
ENTRY DIAMETER (mm)	42	43	44	43	45
PENETRATION (mm)	25	24	24	24	25

J.T.V. =2·21 mm/us
CHARGE FILLED TO 1/2 C.D. HEAD HEIGHT.

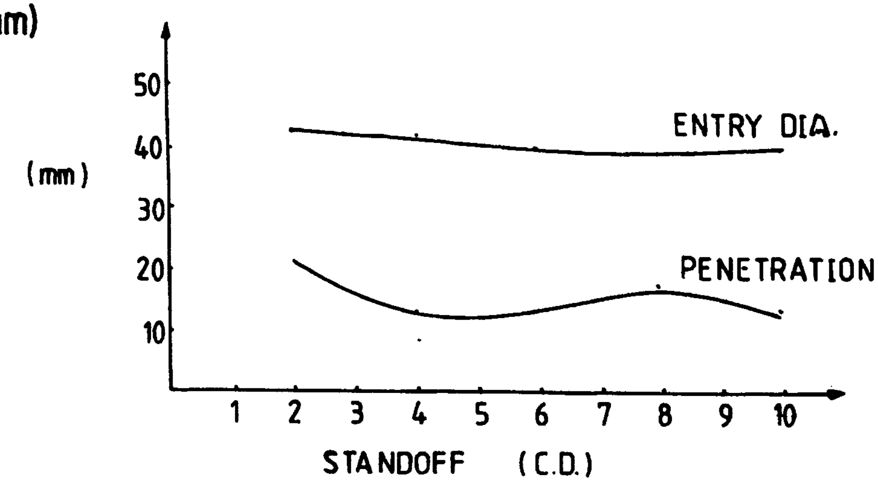


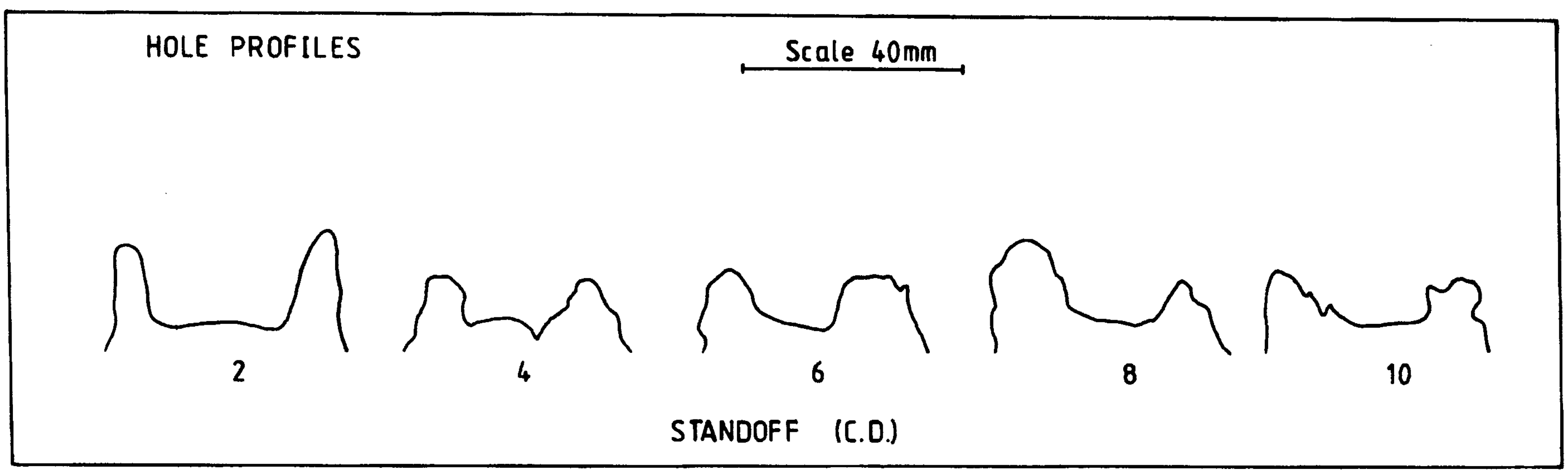


R 60 x 1·95mm LOW CARBON STEEL (Ø60mm)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	42	42	40	39	40
PENETRATION (mm)	21	13	13	18	14

CHARGE FILLED TO 1/2 C.D HEAD HEIGHT.
PERSPEX CASE.
J.T.V. = 1·93 mm/us





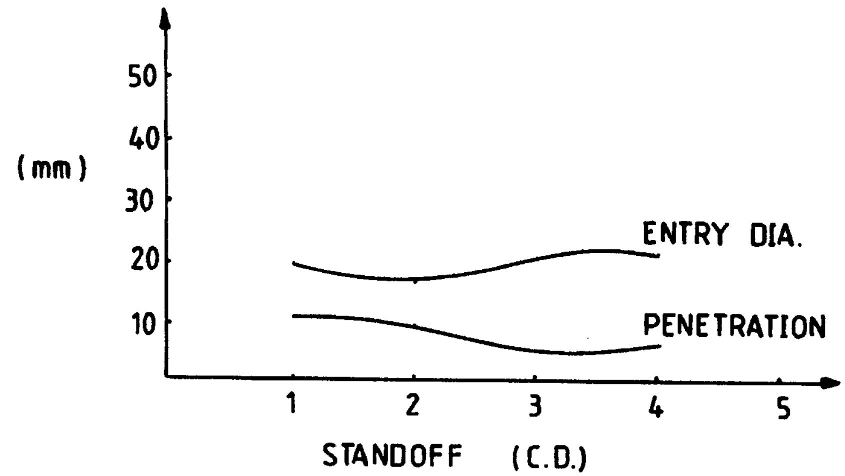
ϕ 25mm L.C.S. DONUT (TUB 20)

STANDOFF (C.D.)	1	2	3	4	
ENTRY DIAMETER (mm)	19	16	20	21	
PENETRATION (mm)	10	9	5	6	

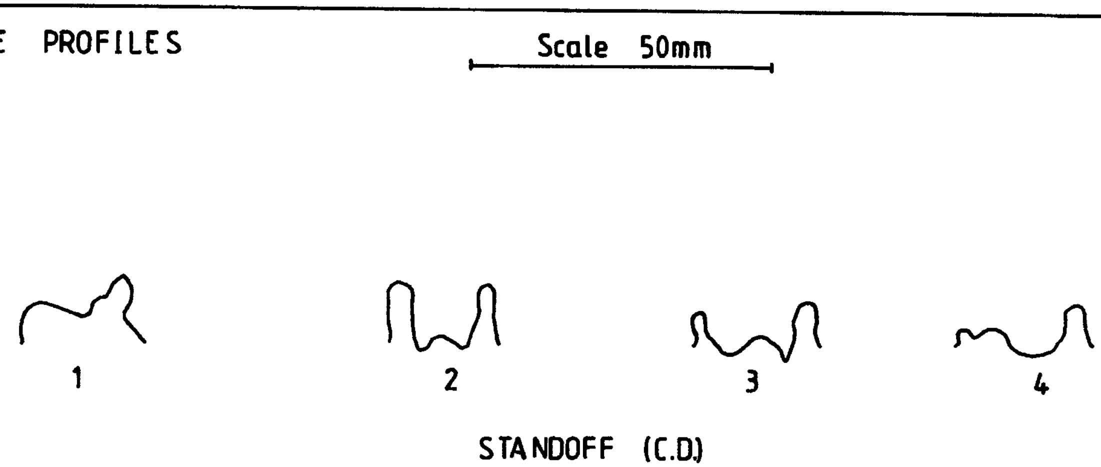
CHARGE FILLED TO 1/2 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 3·23 mm / µs



HOLE PROFILES



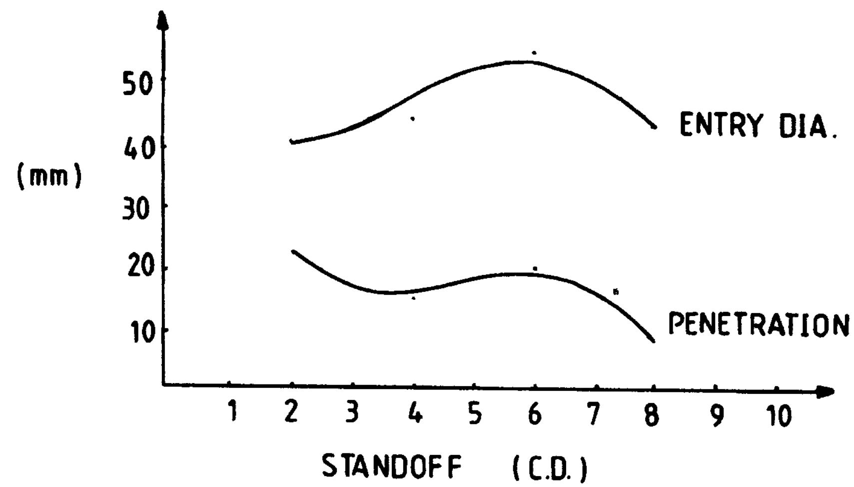
ϕ 60mm L.C.S. DONUT (TUB 04)

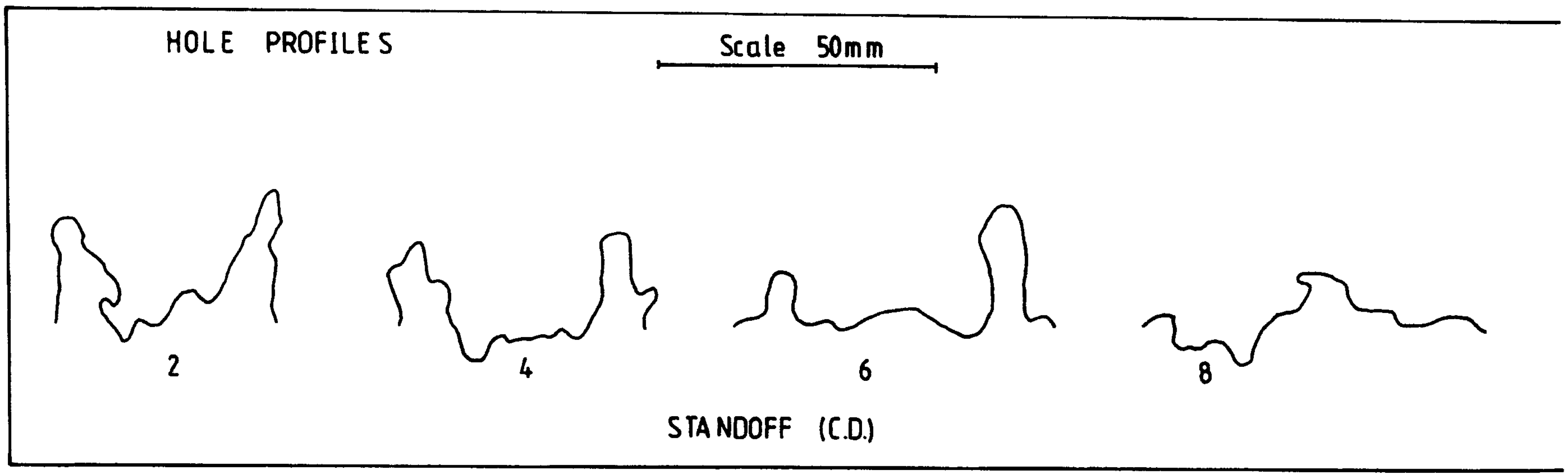
STANDOFF (C.D.)	2	4	6	8	
ENTRY DIAMETER (mm)	40	44	55	43	
PENETRATION (mm)	22	15	20	8	

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 3·12 mm/μs

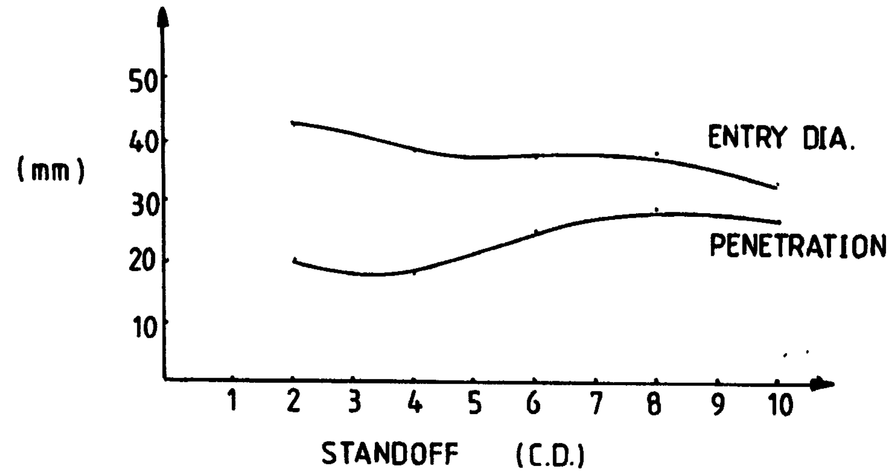


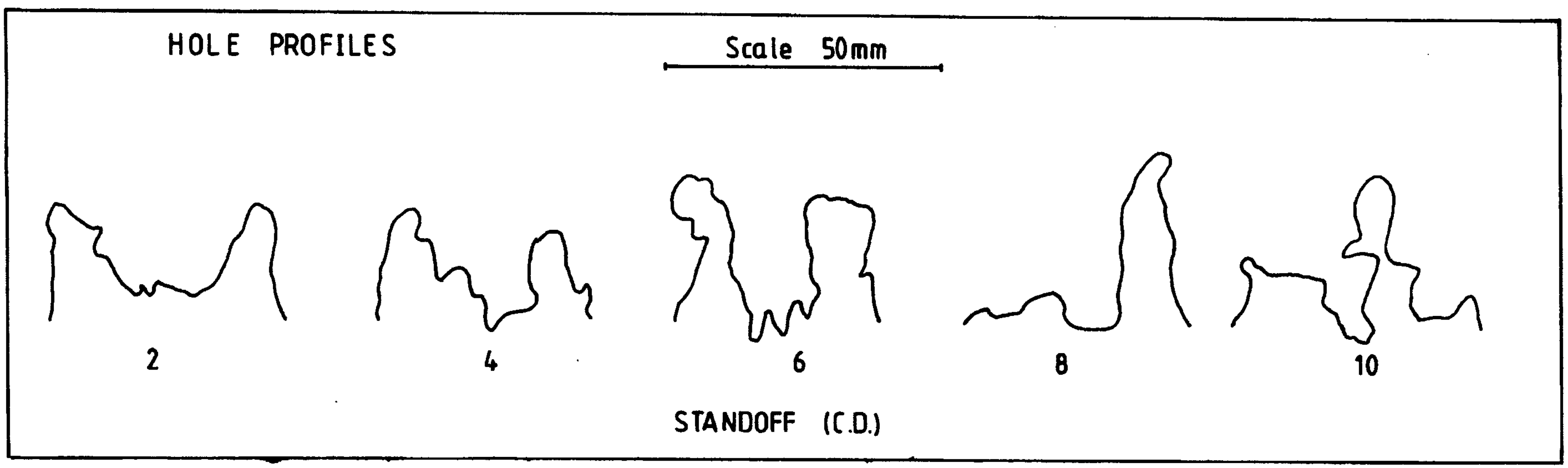


ϕ60mm L.C.S. DONUT (TYPE A)

STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	42	38	37	38	33
PENETRATION (mm)	20	18	25	29	27

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT
ALUMINIUM CASE
J.T.V. = 2·38 mm/μs





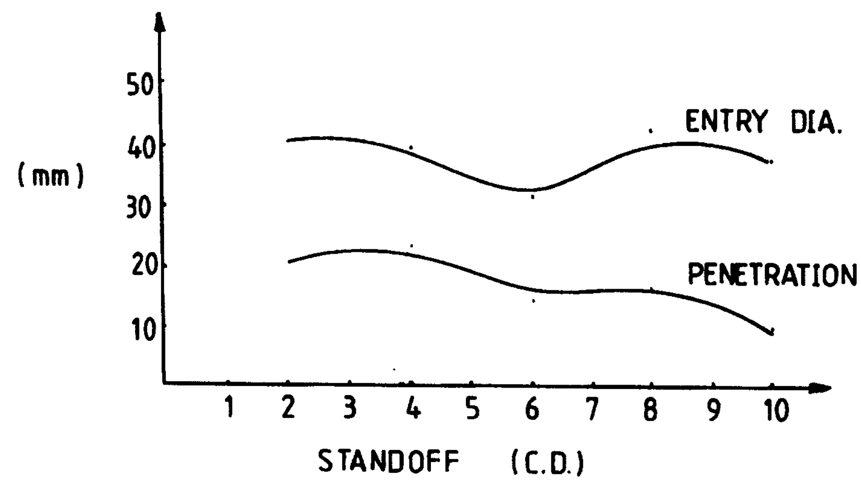
ϕ 60mm L.C.S. DONUT (TYPE B)

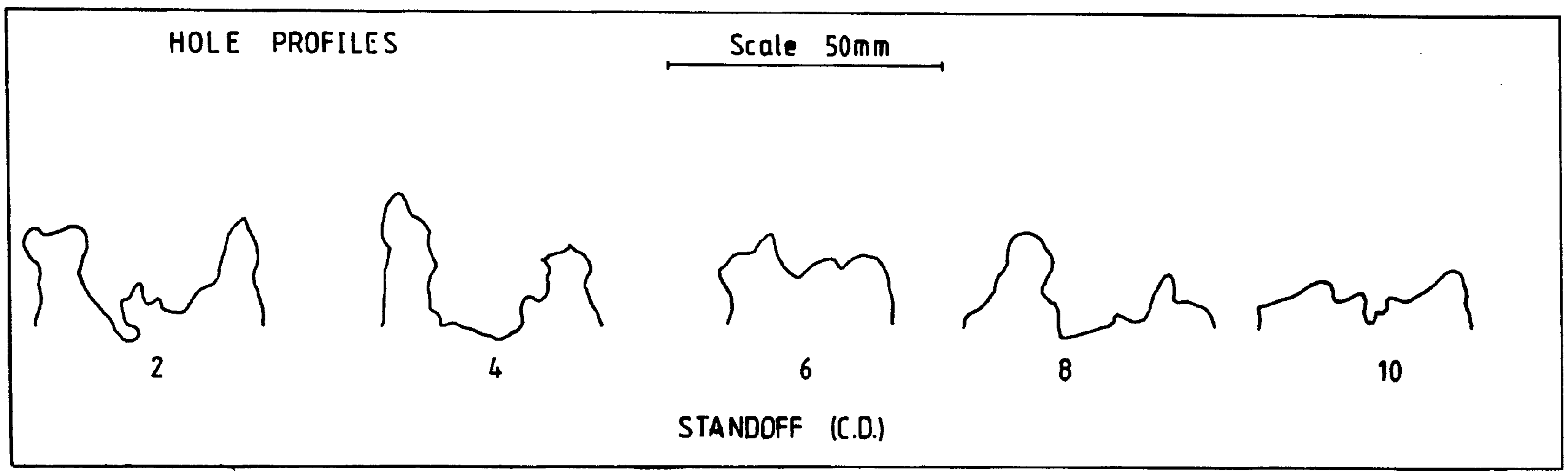
STANDOFF (C.D.)	2	4	6	8	10
ENTRY DIAMETER (mm)	40	39	31	42	37
PENETRATION (mm)	20	23	14	16	9

CHARGE FILLED TO 1/4 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T. V. = 2·58 mm / μs





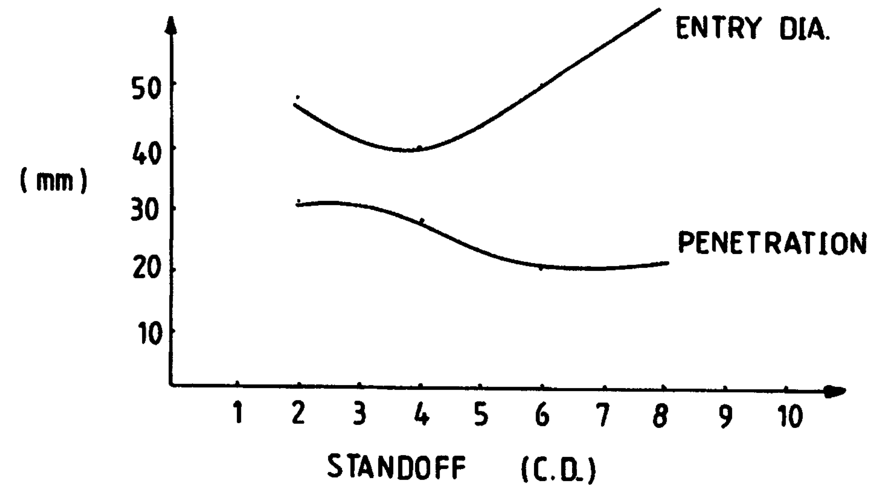
ϕ 80mm L.C.S. DONUT (TYPE C)

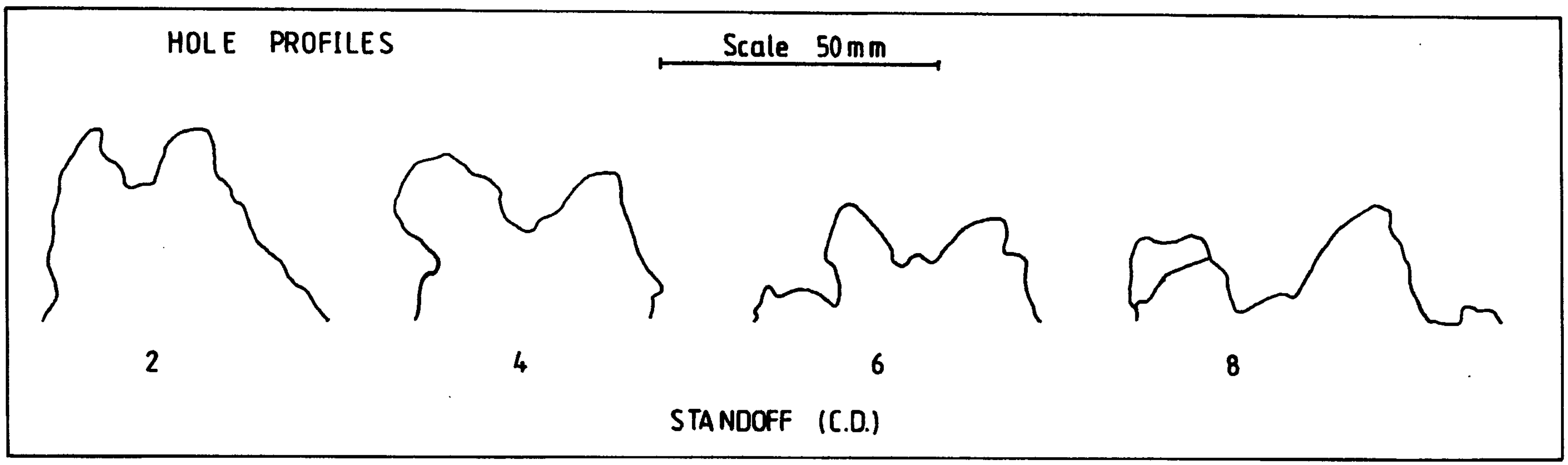
STANDOFF (C.D.)	2	4	6	8	
ENTRY DIAMETER (mm)	48	40	50	63	
PENETRATION (mm)	31	28	20	21	

CHARGE FILLED TO 1/4 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 2·21 mm/µs

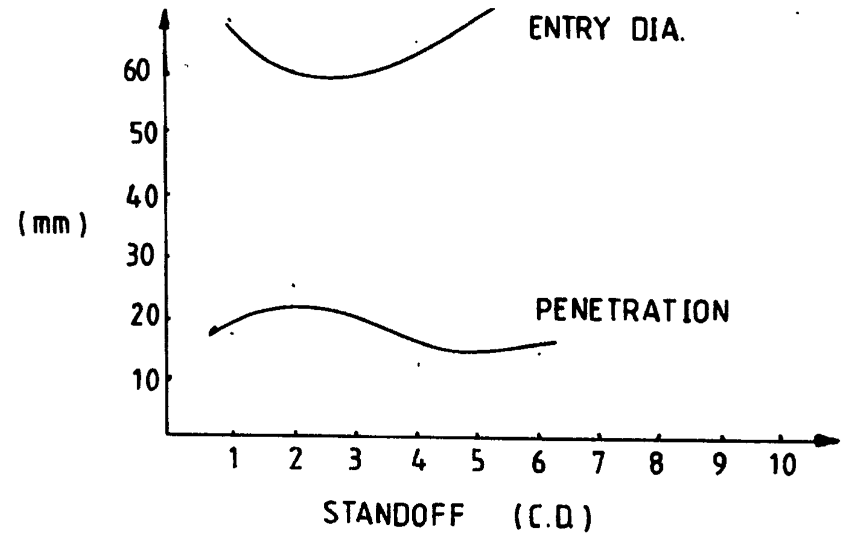


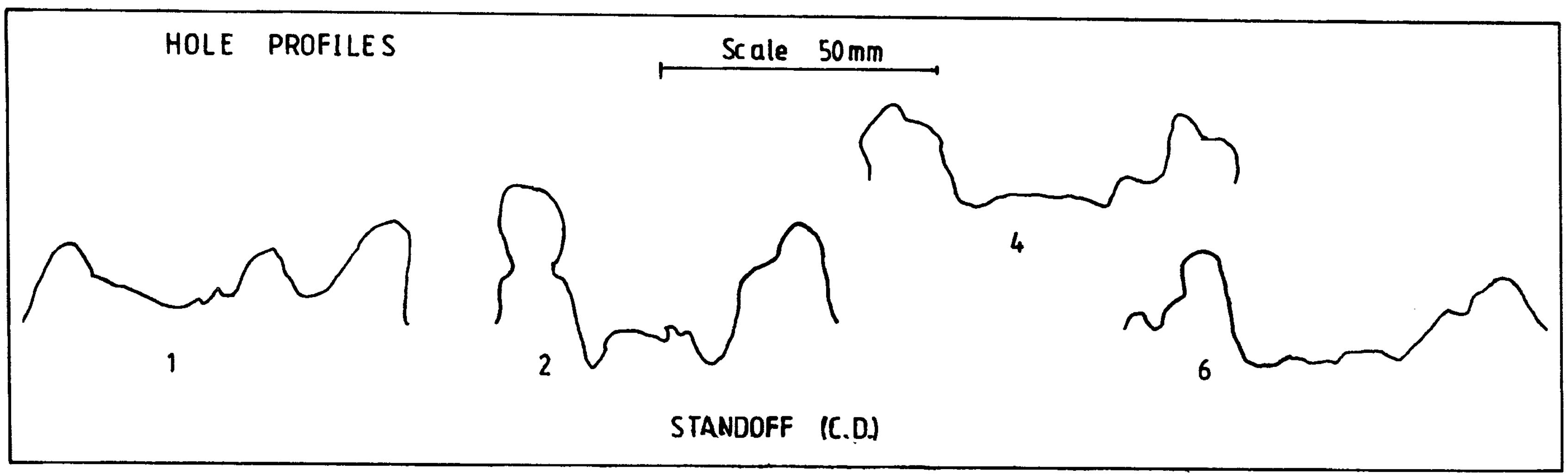


φ 80 mm L.C.S. DONUT (TUB 12)

STANDOFF (C.D.)	1	2	4	6	
ENTRY DIAMETER (mm)	68	60	65	75	
PENETRATION (mm)	17	25	12	14	

CHARGE FILLED TO 1/4 C.D. HEAD HEIGHT
ALUMINIUM CASE
J.T.V. = 2·96 mm / μs





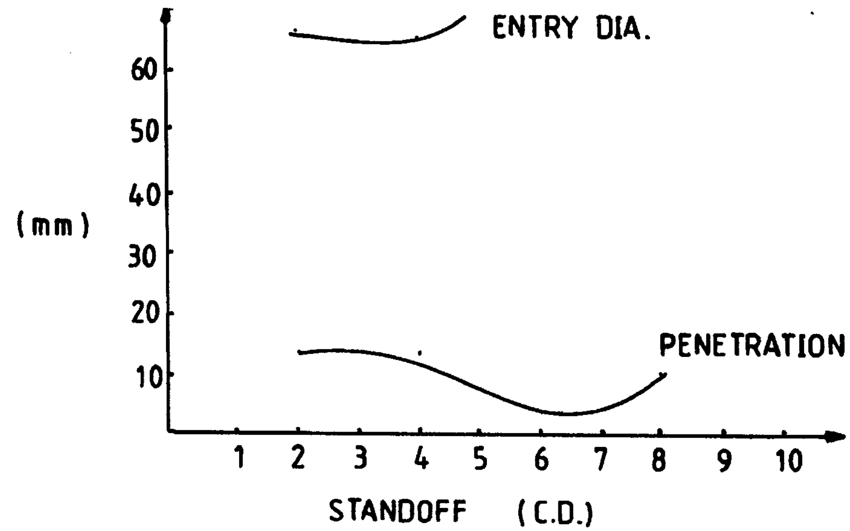
ϕ 80mm L.C.S. DONUT (TUB 13C)

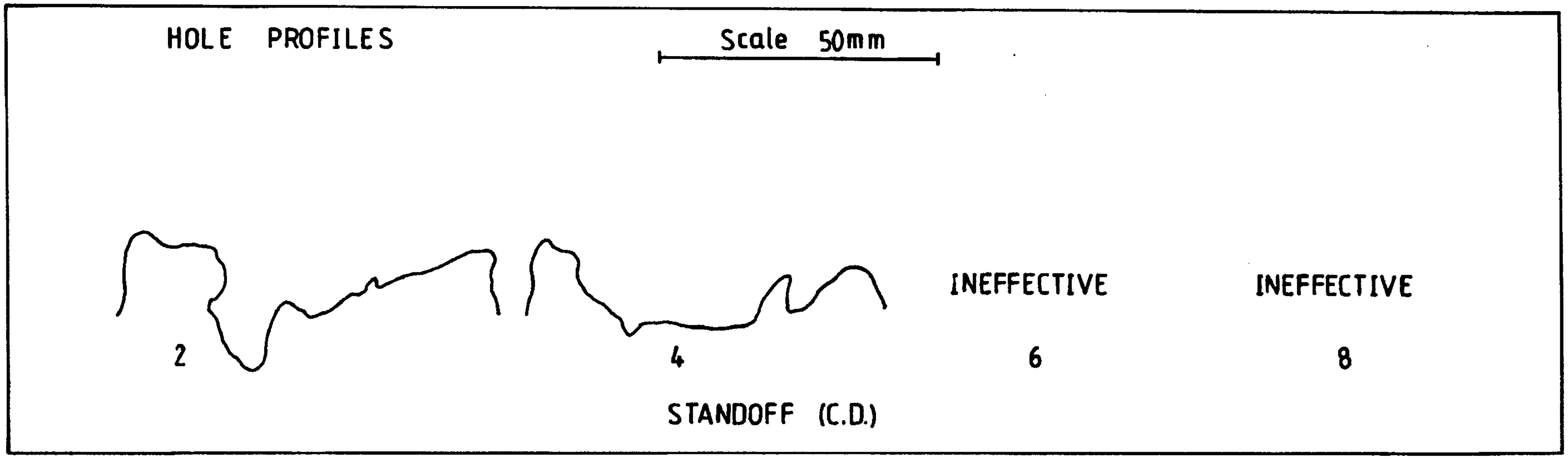
STANDOFF (C.D.)	2	4	6	8	
ENTRY DIAMETER (mm)	66	65	100	120	
PENETRATION (mm)	13	12	4	10	

CHARGE FILLED TO 1/4 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 2·71 mm/µs

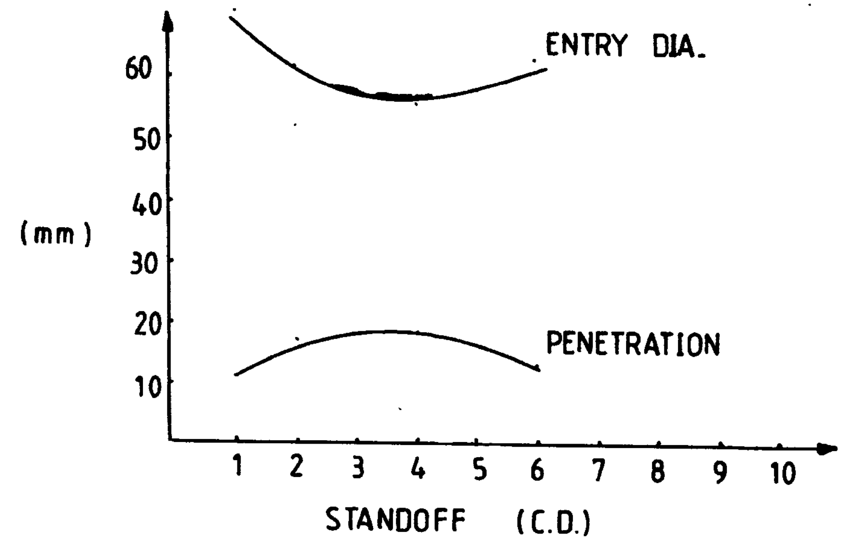


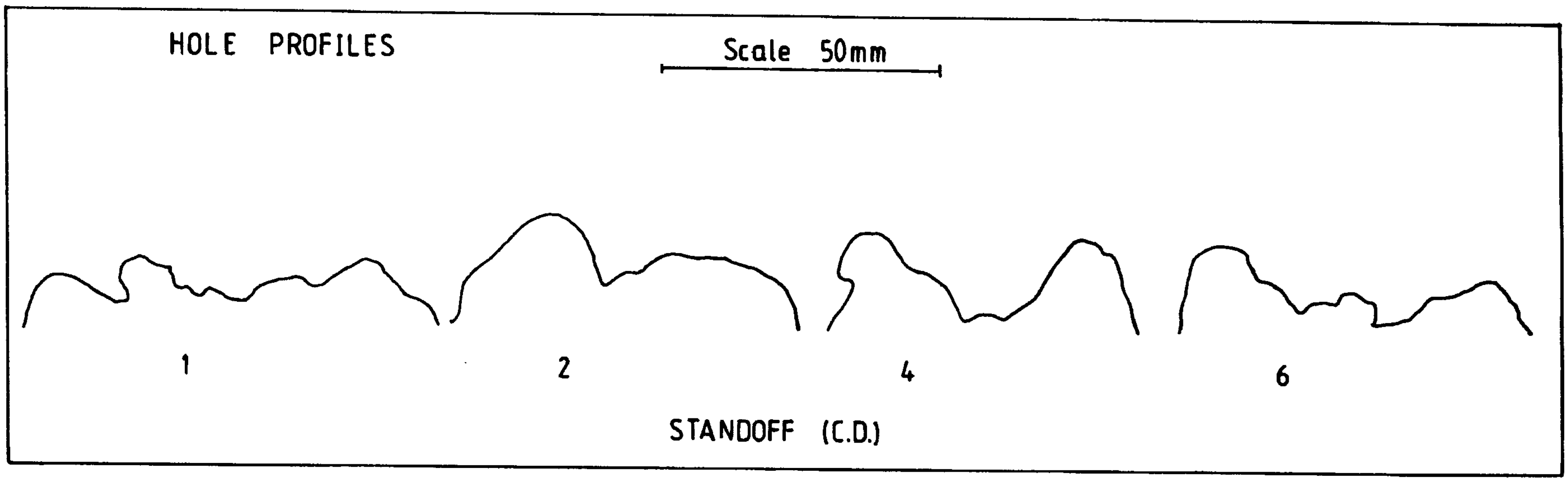


ϕ 80mm L.C.S. DONUT (TUB 17)

STANDOFF (C.D.)	1	2	4	6	
ENTRY DIAMETER (mm)	71	62	56	63	
PENETRATION (mm)	11	18	18	13	

CHARGE FILLED TO 1/4 C.D. HEAD HEIGHT
ALUMINIUM CASE
J.T.V. = 1·92 mm/µs





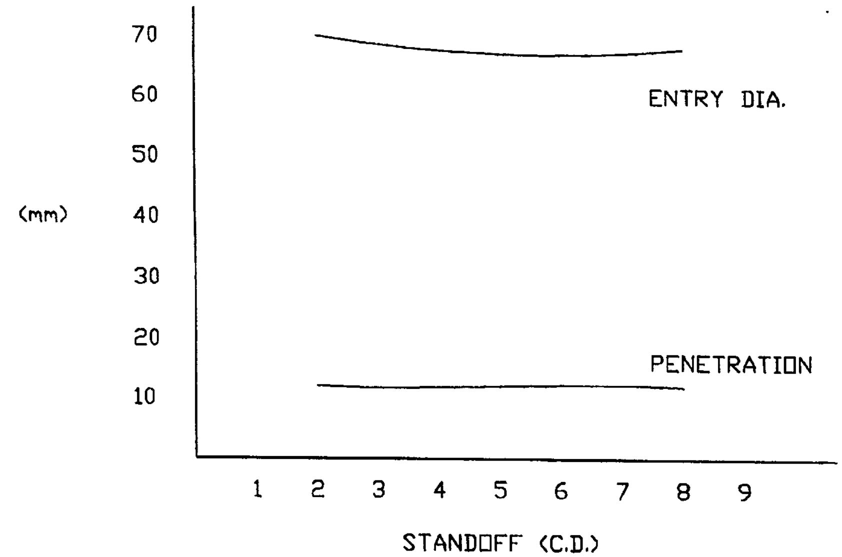
80mm dia. L.C.S. DONUT (Ref.)

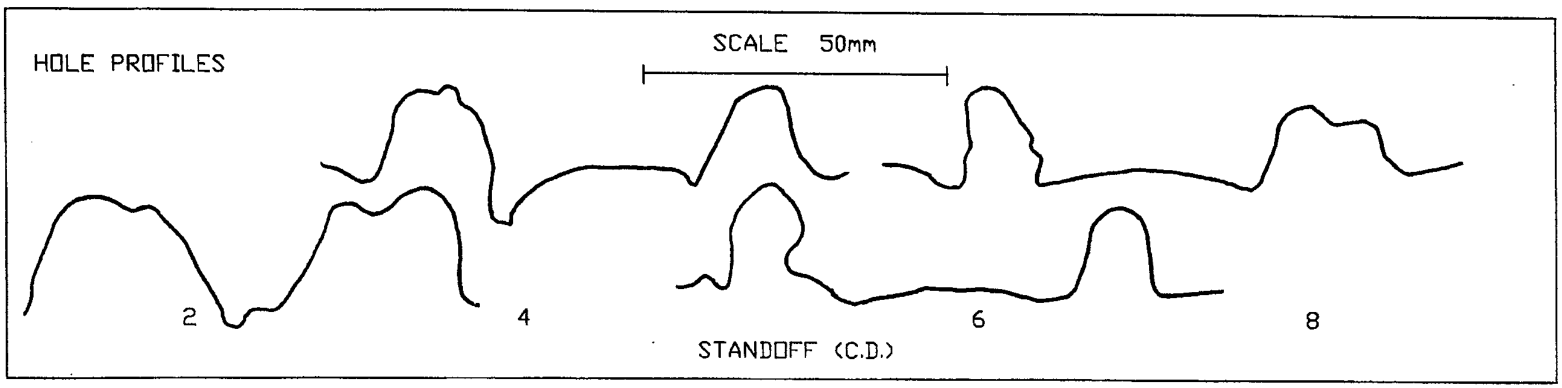
STANDOFF (C.D.)	2	4	6	8
ENTRY DIAMETER (mm)	70	68	67	68
PENETRATION (mm)	12	11	13	12

CHARGE FILLED 1/4 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 2.61 mm/us





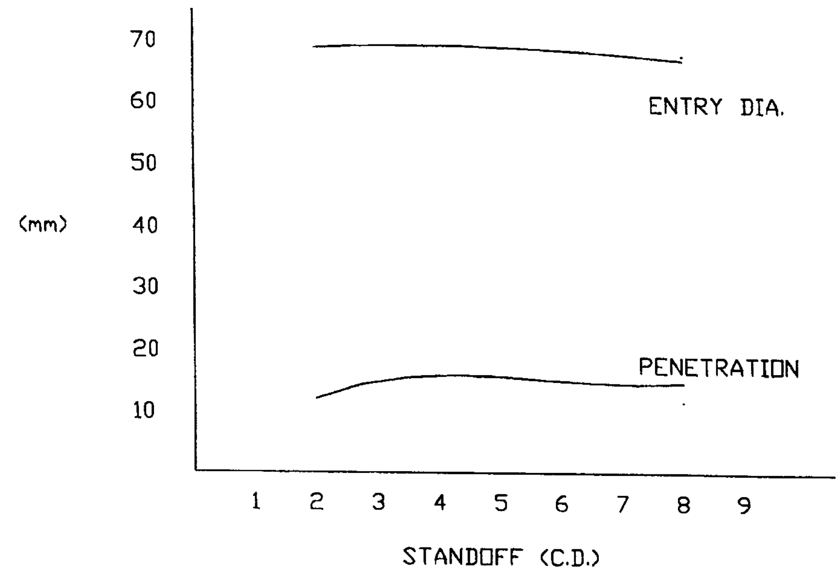
80mm dia. L.C.S. DONUT (Ref.)

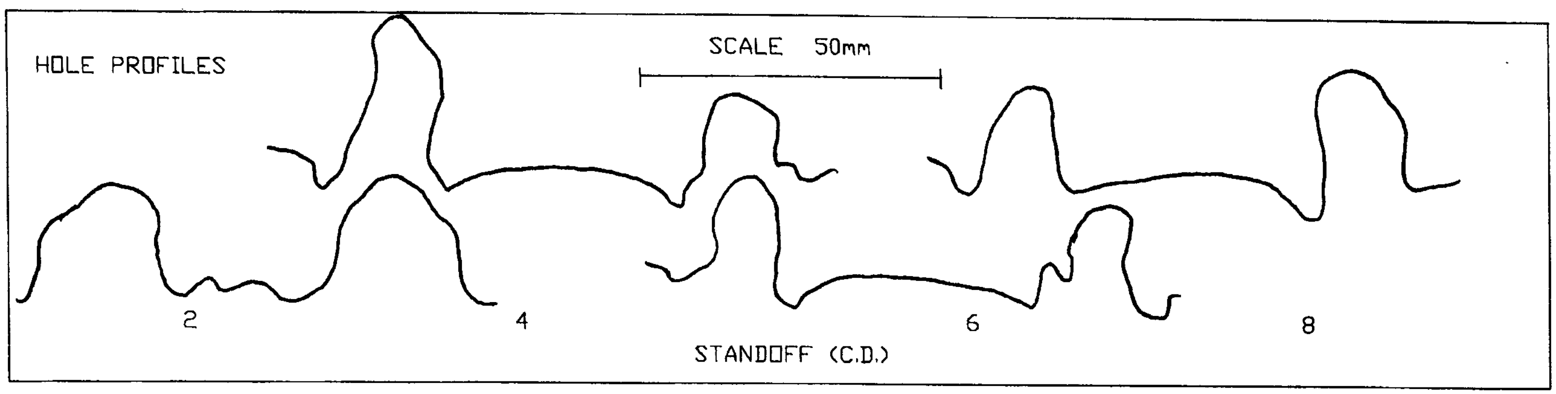
STANDOFF (C.D.)	2	4	6	8
ENTRY DIAMETER (mm)	69	70	69	67
PENETRATION (mm)	12	20	13	15

CHARGE FILLED 1/4 C.D. HEAD HEIGHT

PMMA CASE

J.T.V. = 2.26 mm/us

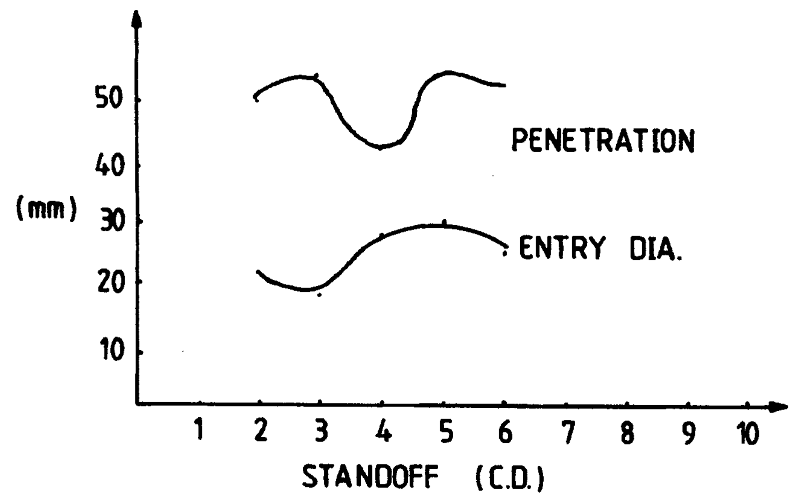


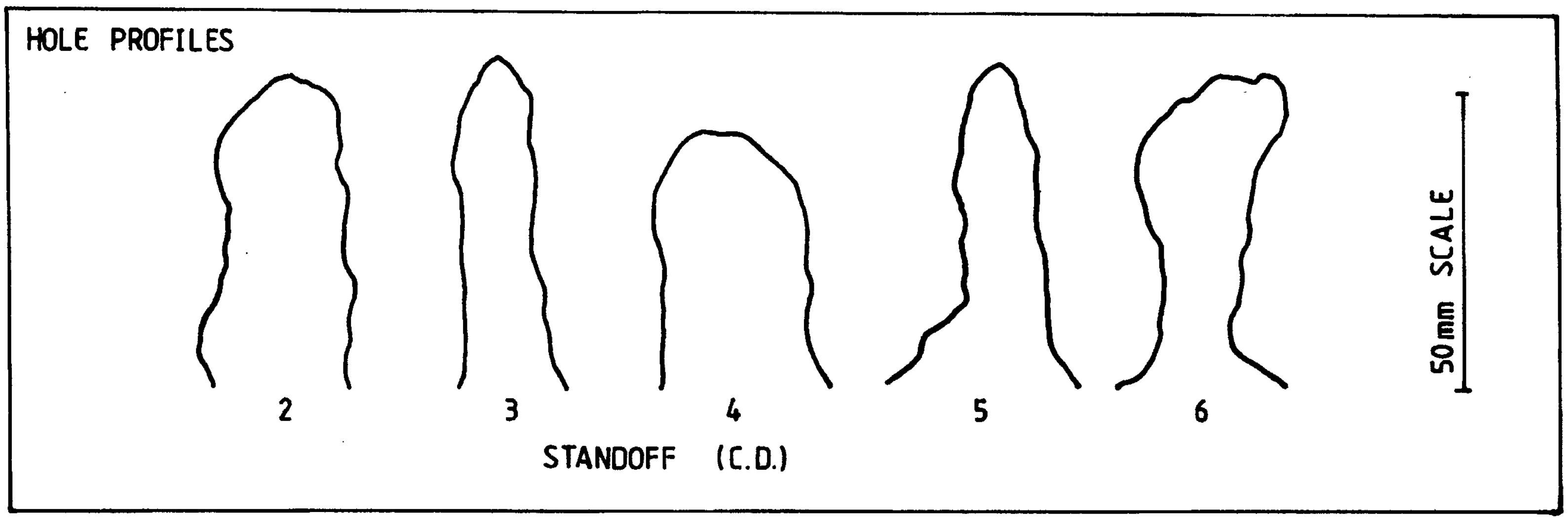


ϕ60mm x 90° x 2 mm GLASS x 1/3 H.H.

STANDOFF (C.D.)	2	3	4	5	6
ENTRY DIAMETER (mm)	22	18	28	30	25
PENETRATION (mm)	50	54	42	55	53

J.T.V = - mm/µs
* FRAGILE LINER

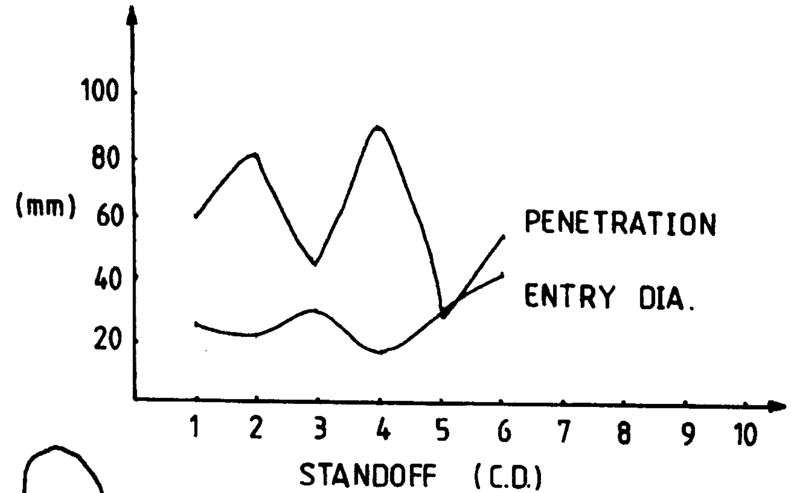


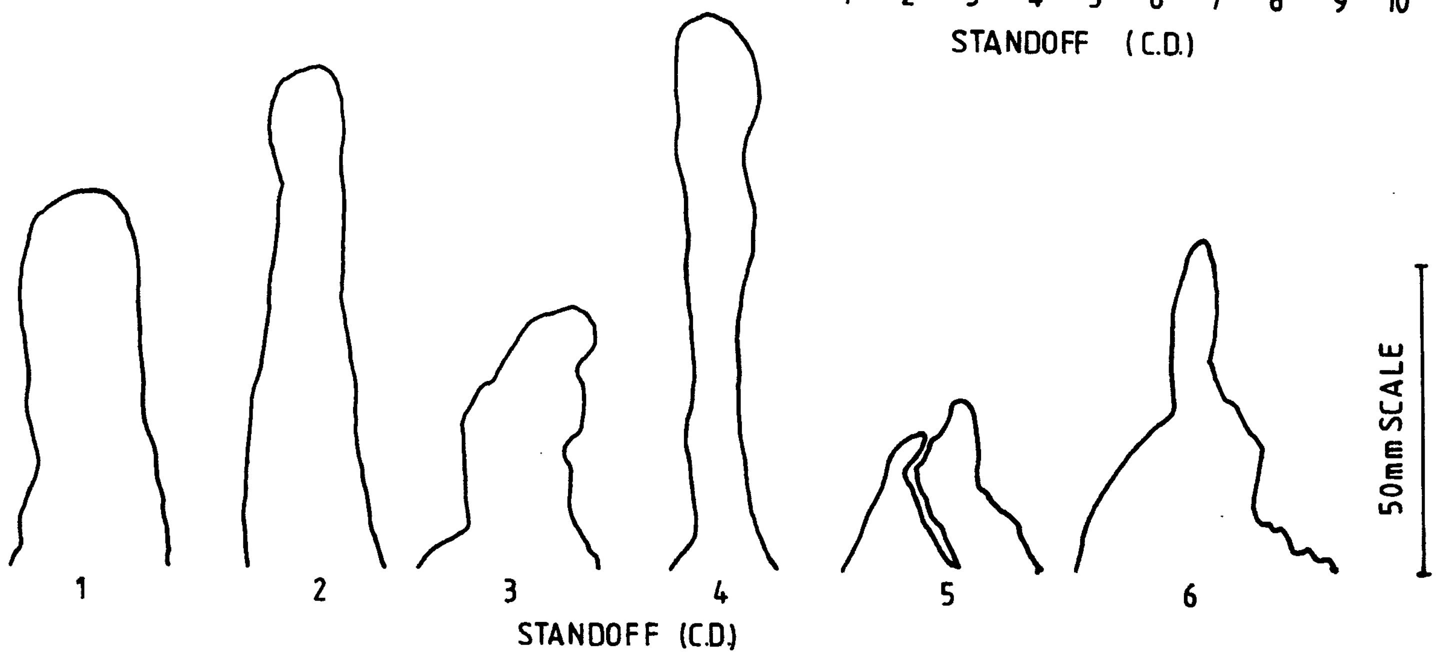


Φ 60mm x 60° x 4mm GLASS x 1/3 H.H.

STANDOFF (C.D.)	1	2	3	4	5	6
ENTRY DIAMETER (mm)	25	21	30	16	30	42
PENETRATION (mm)	60	80	44	89	28	54

J.T.V. = 5·95mm/μs

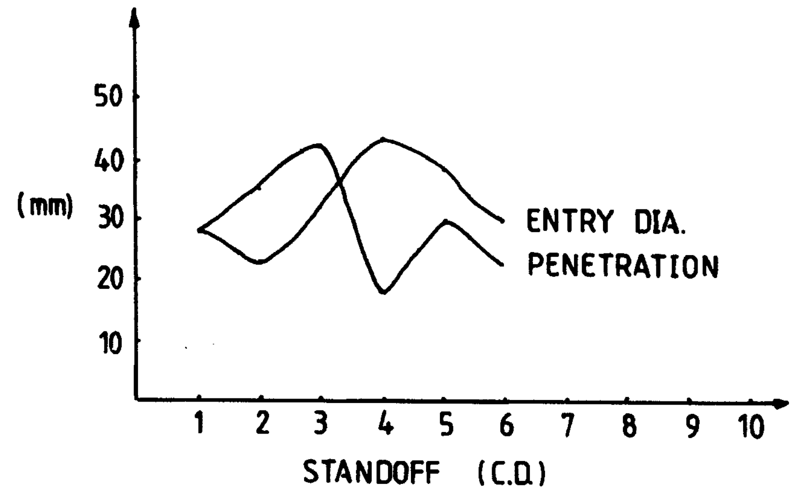


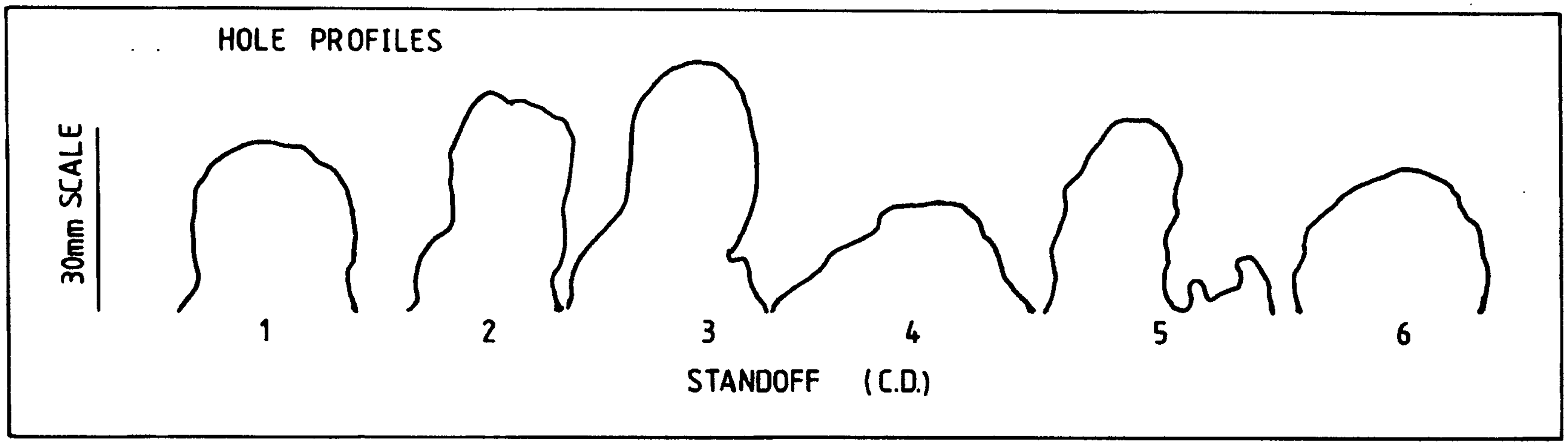


ϕ 60mm x 90° x 4mm GLASS x 1/4 H.H.

STANDOFF (C.D.)	1	2	3	4	5	6
ENTRY DIAMETER (mm)	28	23	32	43	38	30
PENETRATION (mm)	28	35	42	18	30	23

J.T.V. = 3·1 mm/μs

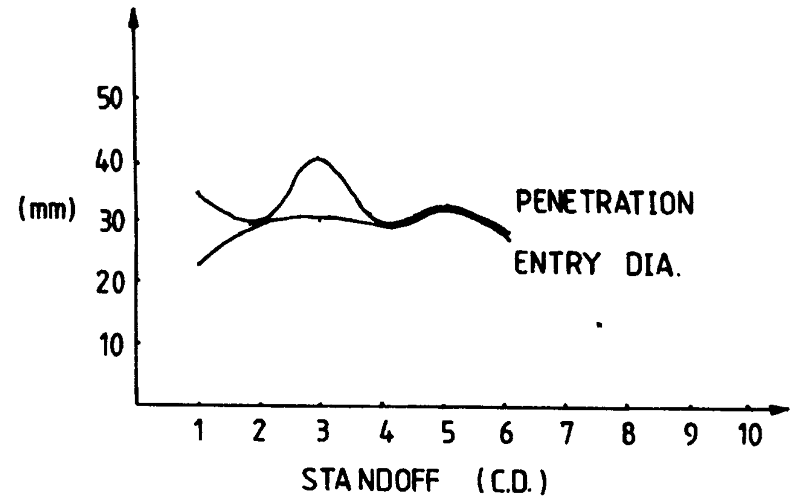


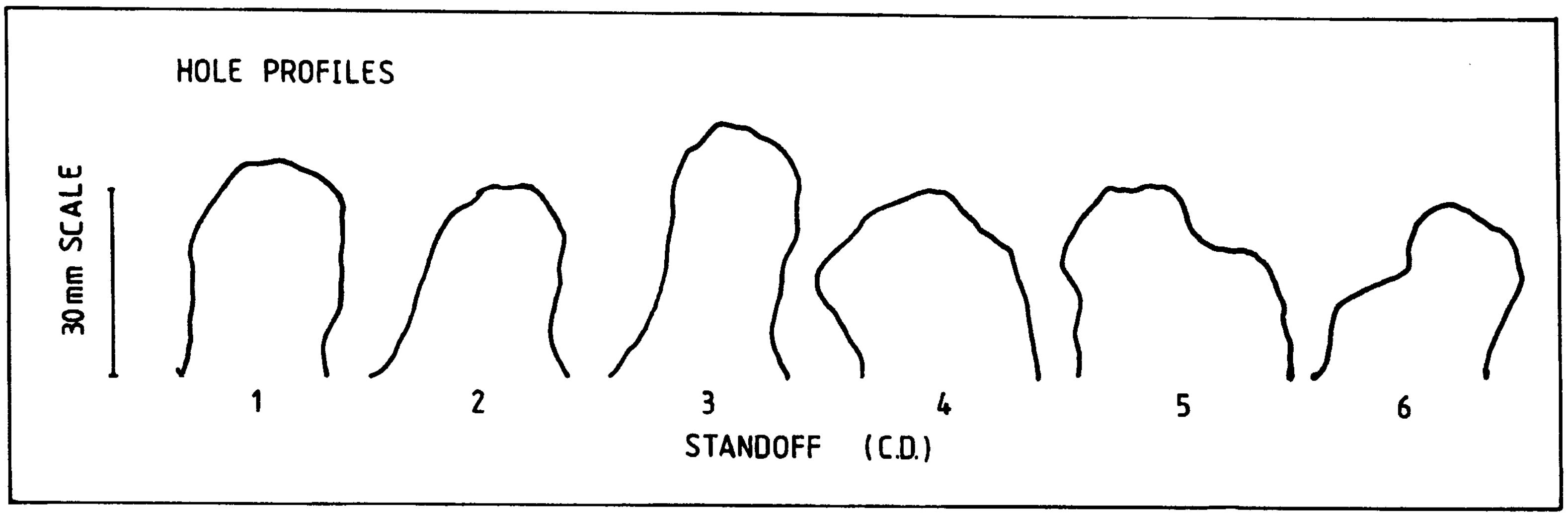


Φ60mm x 90° x 4mm GLASS x 1/3 H.H.

STANDOFF (C.D.)	1	2	3	4	5	6
ENTRY DIAMETER (mm)	23	30	30	29	33	27
PENETRATION (mm)	35	30	40	29	33	28

J.T.V. = 3·8 mm/μs

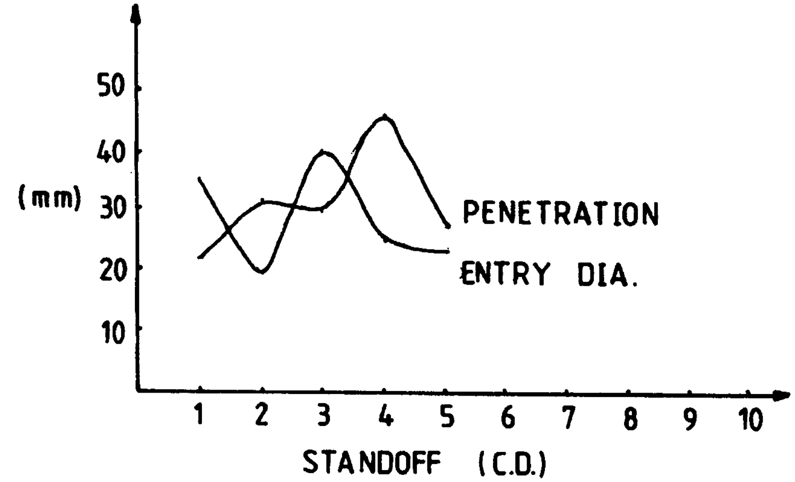


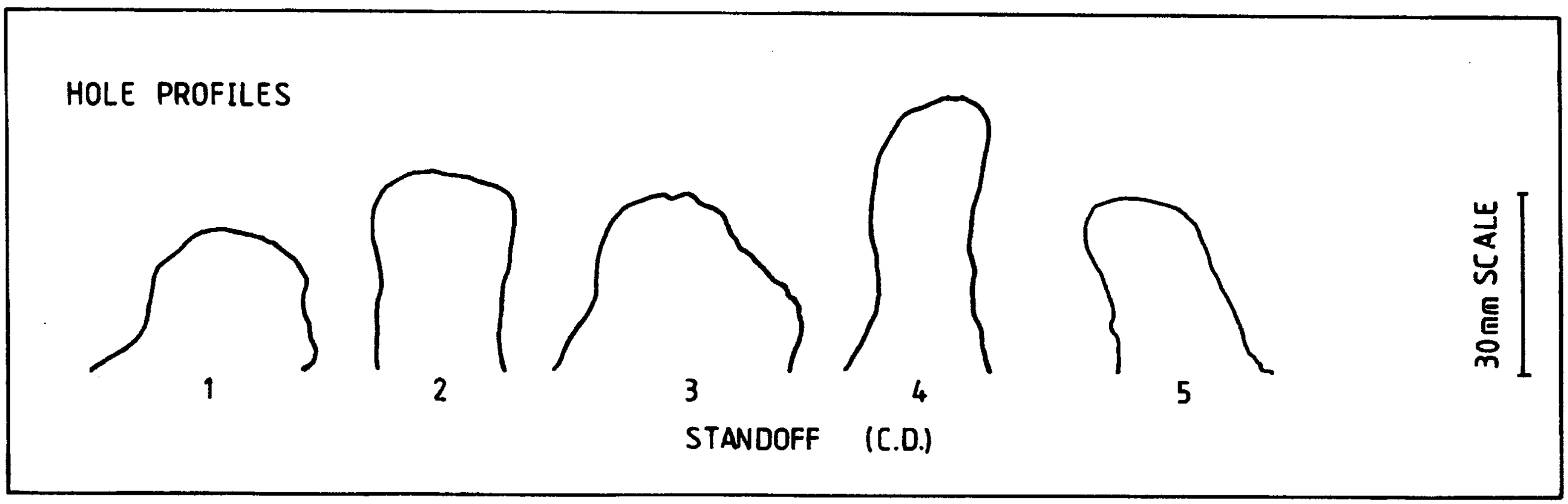


Φ60mm x 105° x 4mm GLASS x 1/4 H.H.

STANDOFF (C.D.)	1	2	3	4	5	6
ENTRY DIAMETER (mm)	35	20	40	25	24	-
PENETRATION (mm)	22	32	30	46	28	-

J.T.V. = 4·03 mm/μs

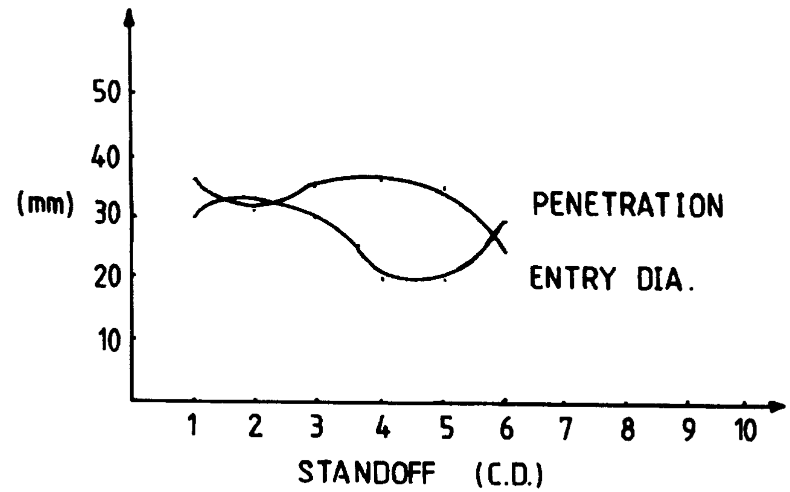


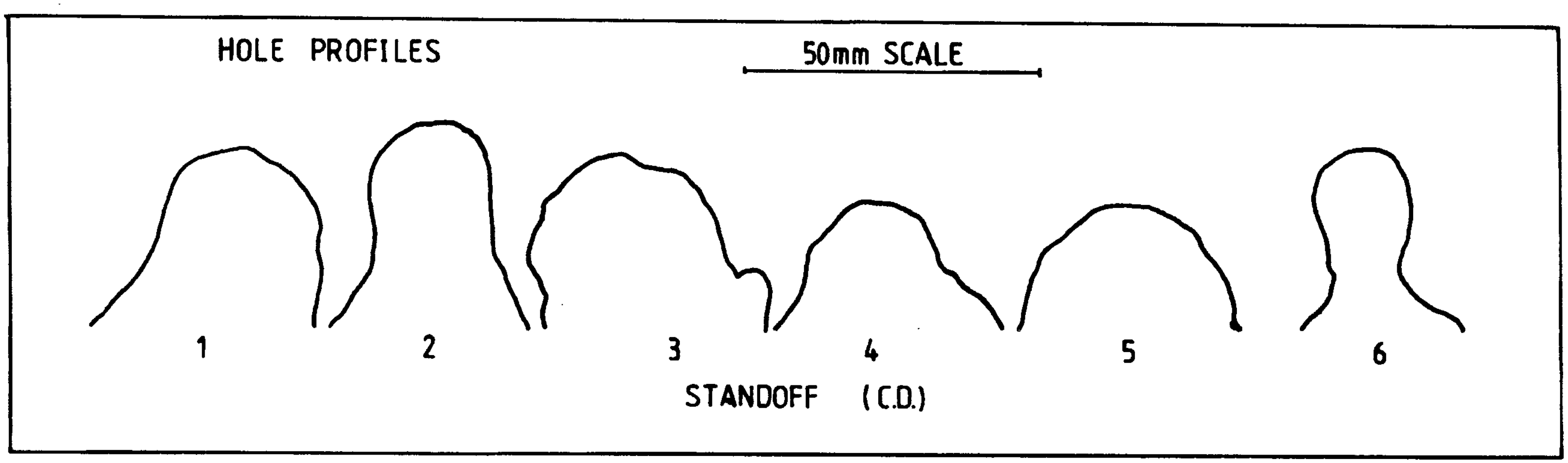


ϕ60mm x 105° x 4mm GLASS x 1/3 H.H.

STANDOFF (C.D.)	1	2	3	4	5	6
ENTRY DIAMETER (mm)	36	31	35	36	35	25
PENETRATION (mm)	30	33	30	20	20	30

J.T.V. = – mm/μs

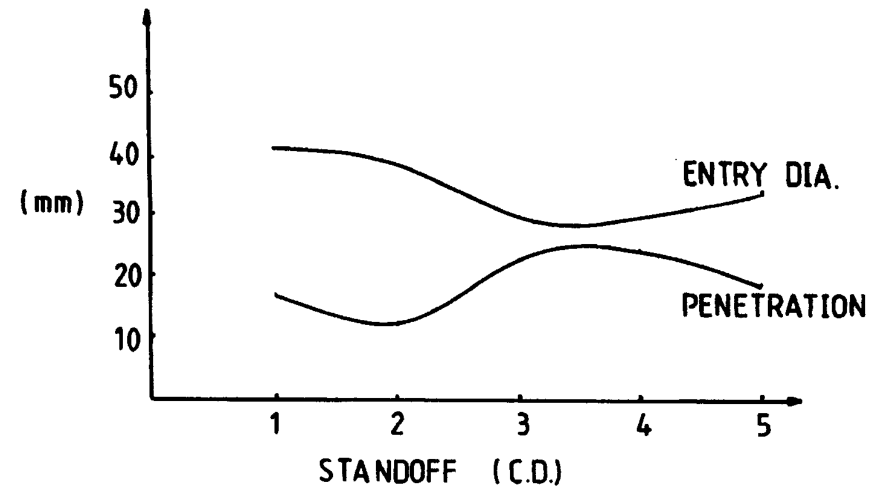


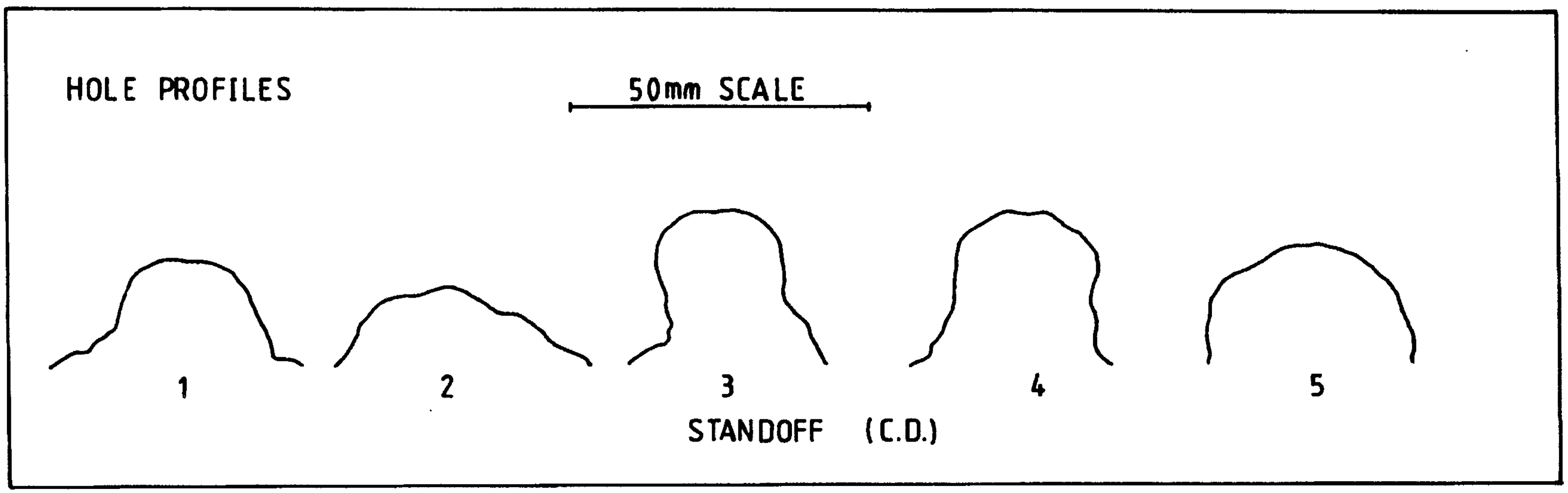


Ø60 × 110° × 4mm GLASS × 1/3 H.H.

STANDOFF (C.D.)	1	2	3	4	5
ENTRY DIAMETER (mm)	41	40	30	31	34
PENETRATION (mm)	17	12	25	25	19

J.T.V. = 2·17 mm/us

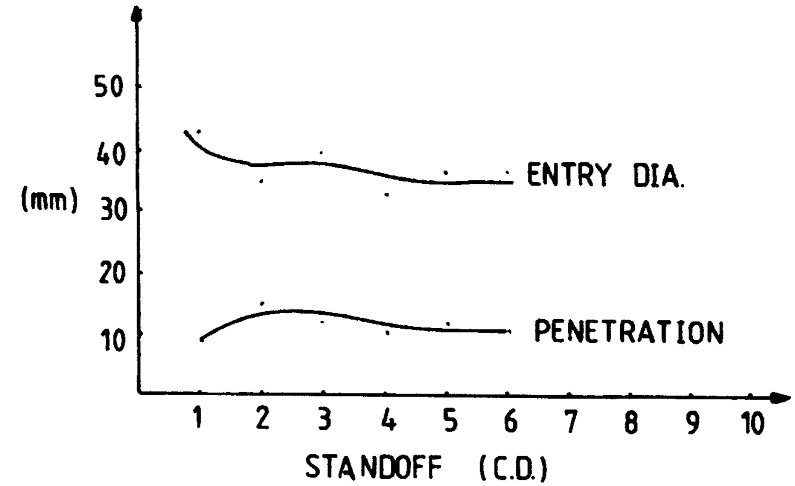


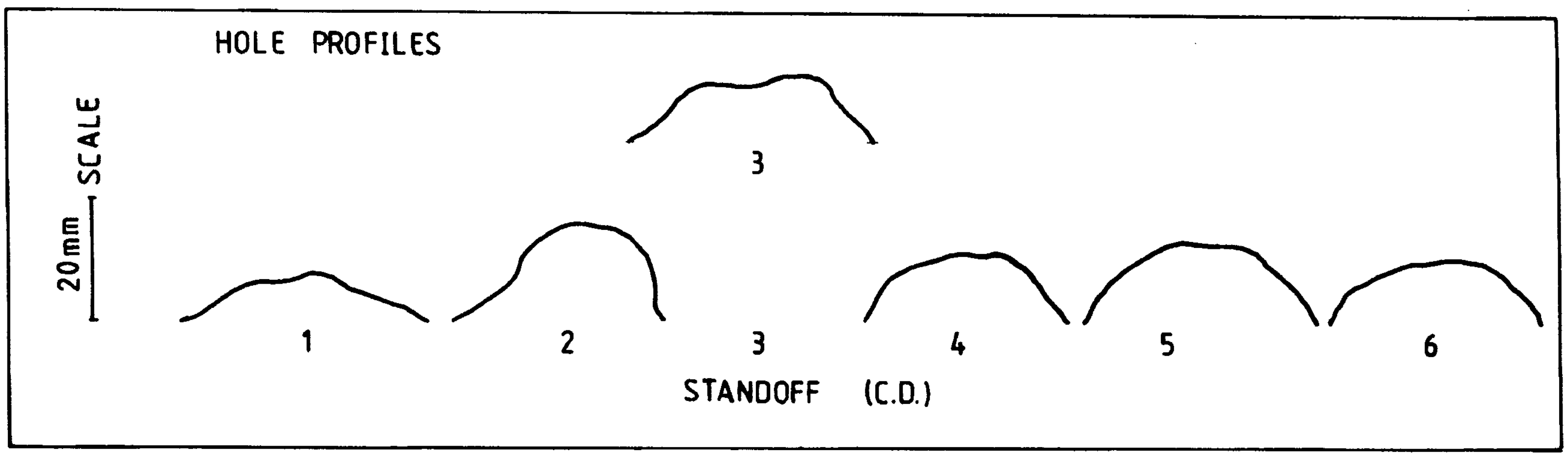


ϕ 60mm x 120° x 4mm GLASS x 1/4 H.H.

STANDOFF (C.D.)	1	2	3	4	5	6
ENTRY DIAMETER (mm)	43	35	40	33	37	37
PENETRATION (mm)	9	15	12	10	12	11

J.T.V. = 2·17 mm/μs

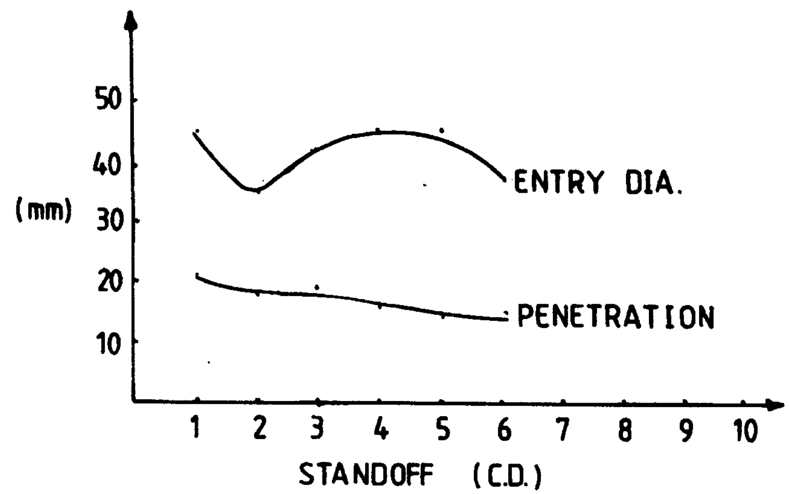


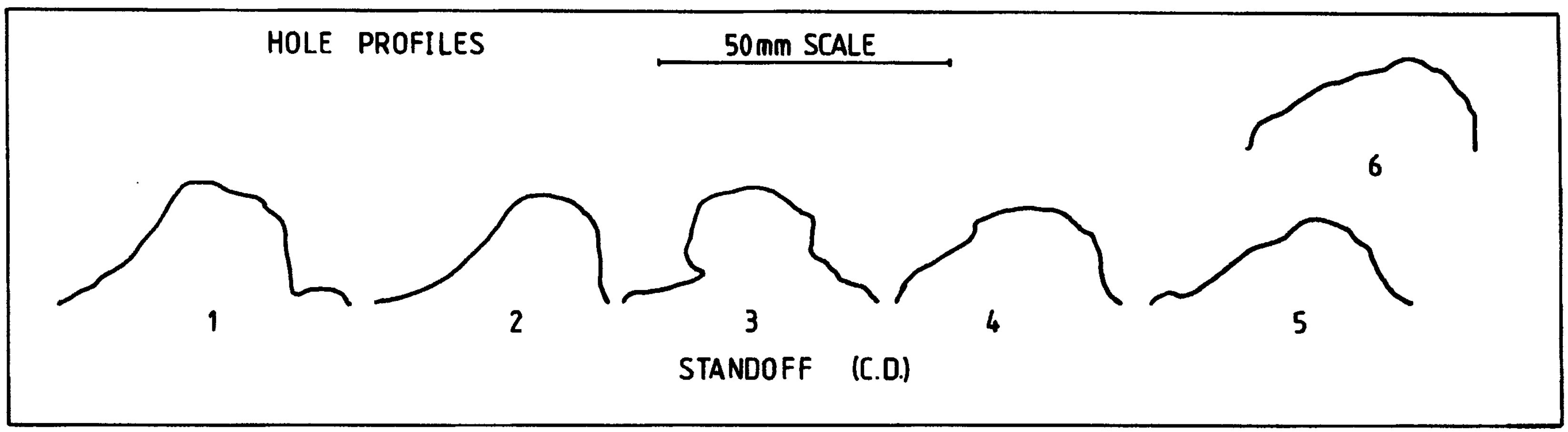


ϕ 60mm x 120° x 4mm GLASS x 1/2 H.H.

STANDOFF (C.D.)	1	2	3	4	5	6
ENTRY DIAMETER (mm)	45	35	42	45	45	37
PENETRATION (mm)	21	18	19	16	14	15

J.T.V = 2·8 mm/μs

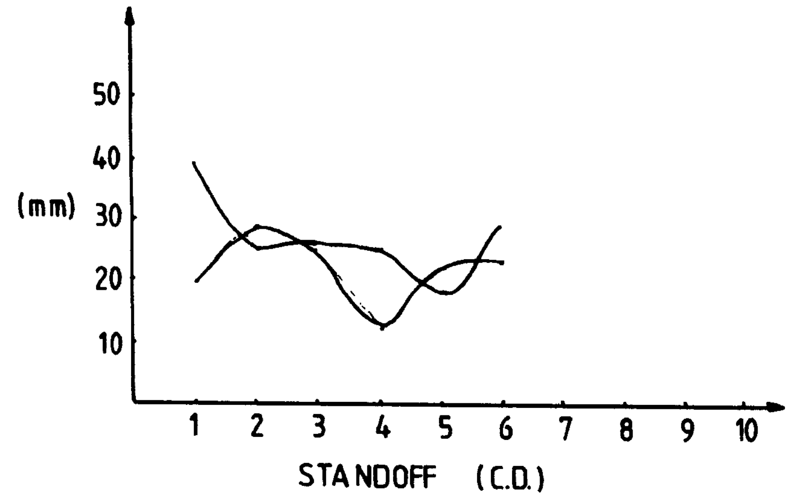


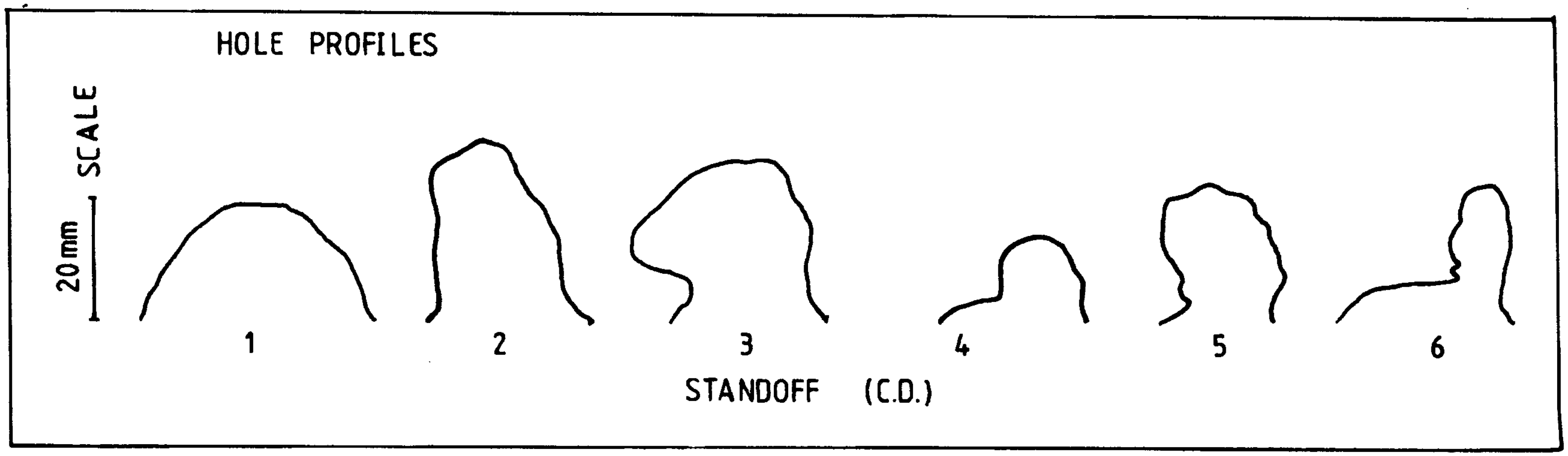


ϕ 60mm x HEMI. x 4mm GLASS x 1/4 H.H.

STANDOFF (C.D.)	1	2	3	4	5	6
ENTRY DIAMETER (mm)	39	25	26	25	18	29
PENETRATION (mm)	20	29	25	12	22	23

J.T.V. = 4·1 mm/μs

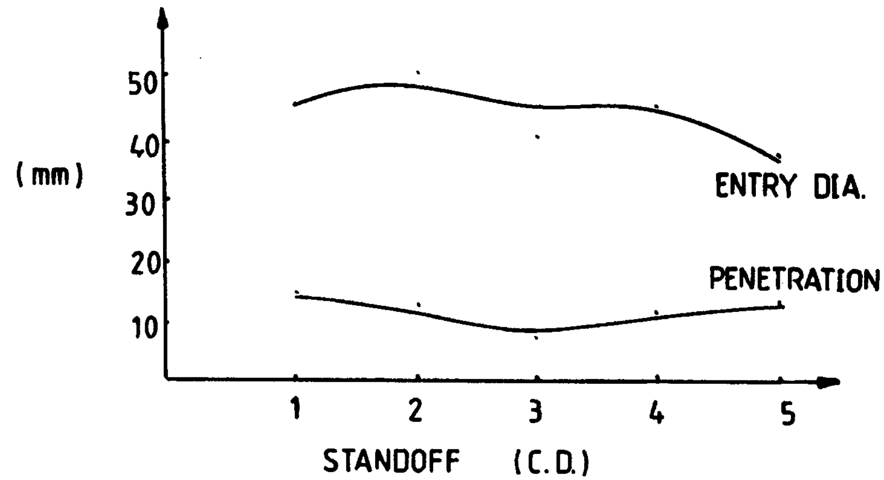


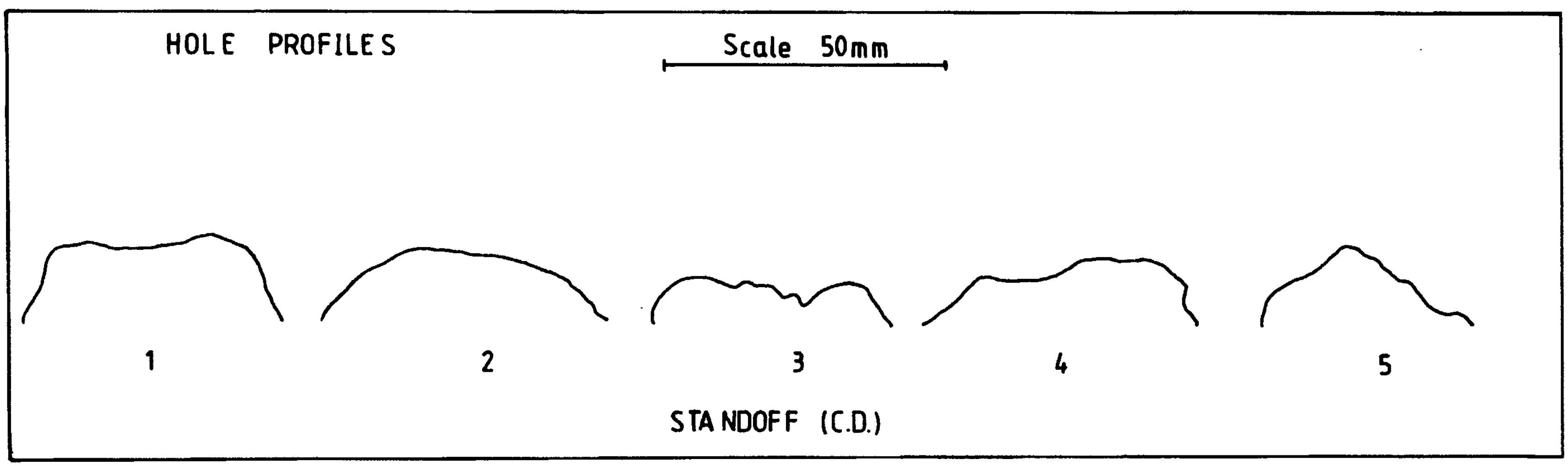


ϕ 60 x R40 x 4 mm MAGNESIUM (CAST)

STANDOFF (C.D.)	1	2	3	4	5
ENTRY DIAMETER (mm)	45	50	40	45	37
PENETRATION (mm)	14	12	7	11	13

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT
ALUMINIUM CASE
J.T.V. = 3·17 mm / μs





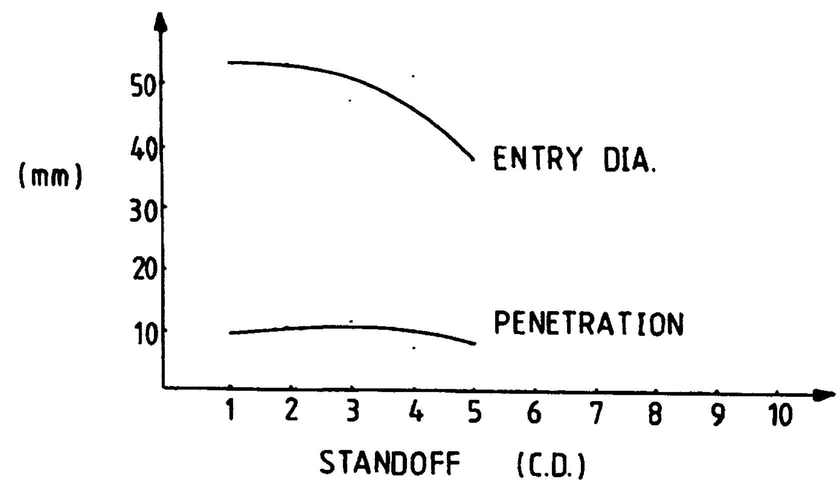
R 60 x Φ60mm x 4mm CAST MAGNESIUM

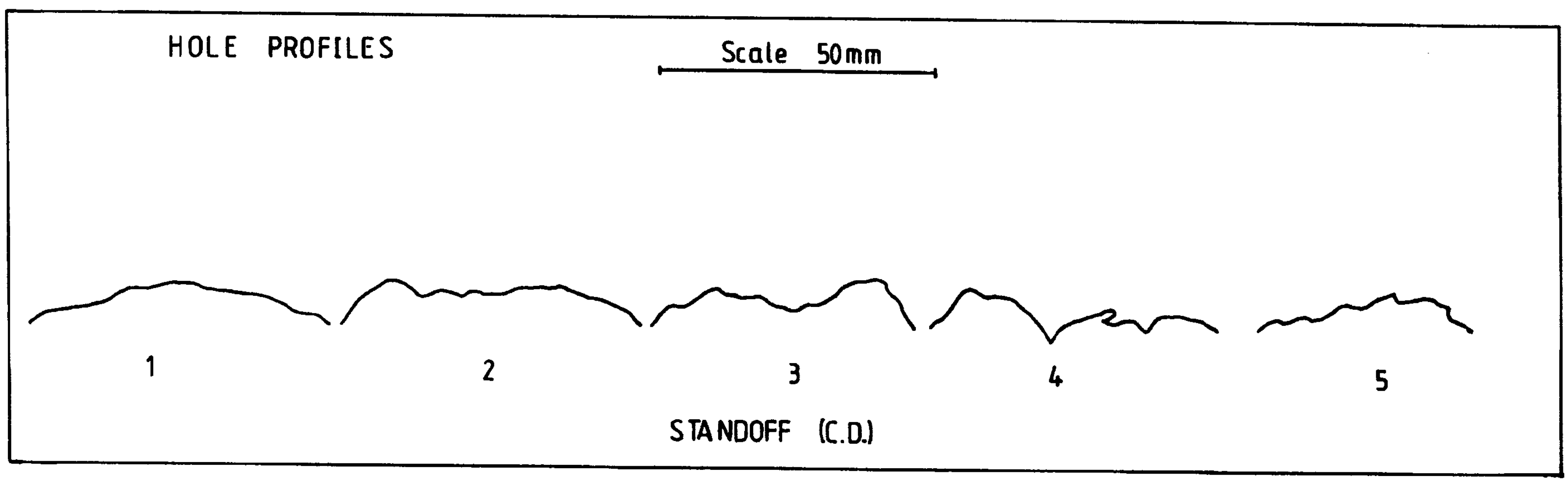
STANDOFF (C.D.)	1	2	3	4	5
ENTRY DIAMETER (mm)	53	53	47	51	38
PENETRATION (mm)	9	10	11	7	8

CHARGE FILLÊD TO 1/3 C.D. HEAD HEIGHT

ALUMINIUM CASE.

J.T.V. = 3·085 mm/µs

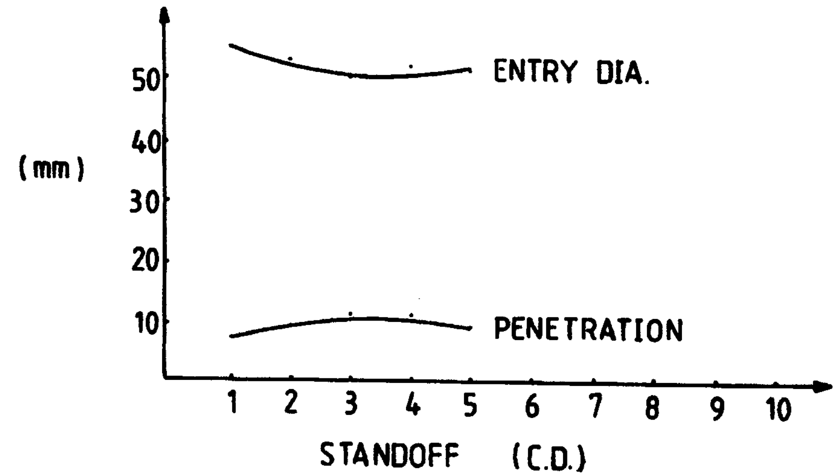


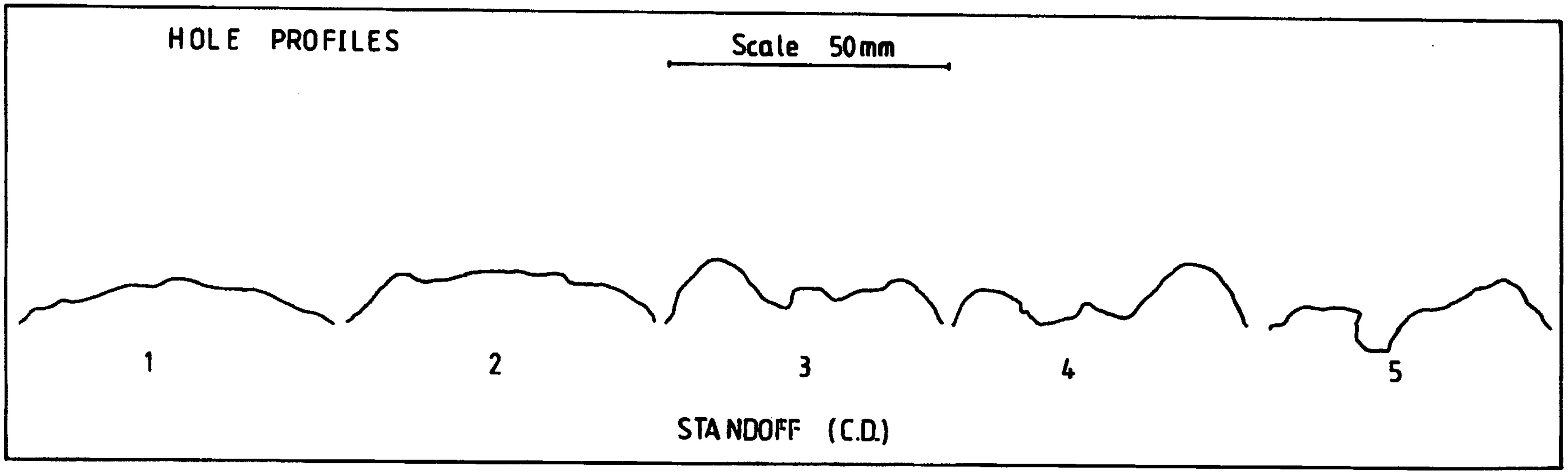


R 60 x Φ60mm x 4mm CAST MAGNESIUM

STANDOFF (C.D.)	1	2	3	4	5
ENTRY DIAMETER (mm)	56	53	50	52	51
PENETRATION (mm)	7	9	11	11	9

CHARGE FILLED TO 1/2 C.D. HEAD HEIGHT
ALUMINIUM CASE
J.T.V. = 3·42 mm / μs





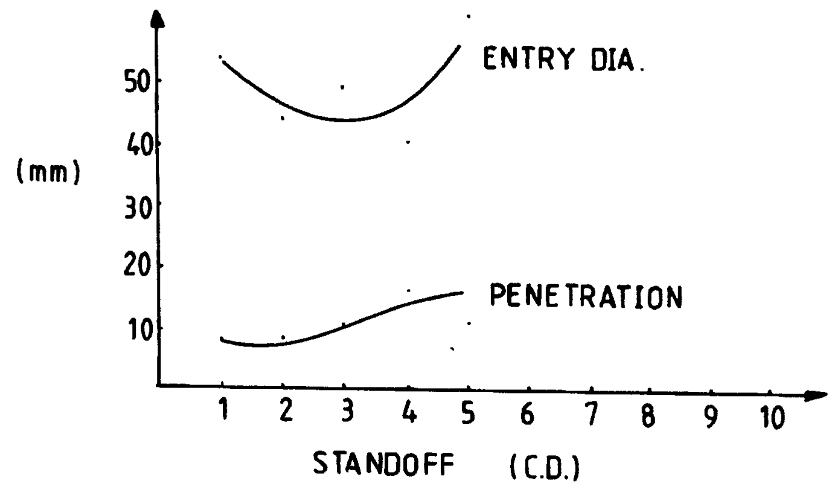
R 60 x Ø60mm x 3·3mm ZIRCONIUM

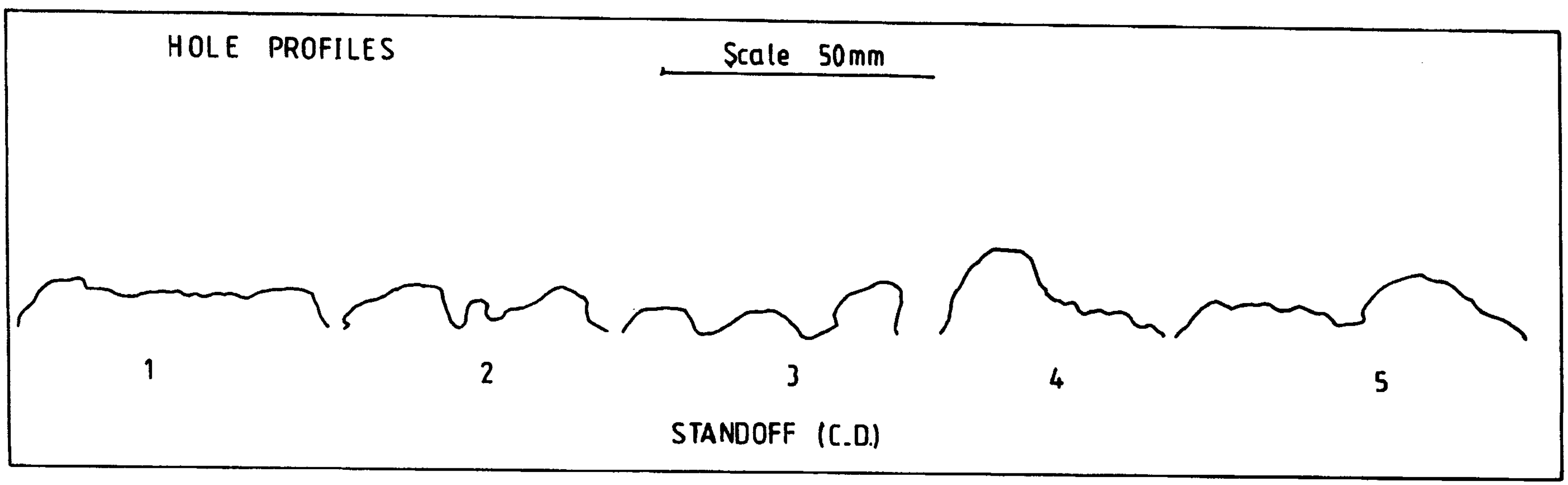
STANDOFF (C.D.)	1	2	3	4	5
ENTRY DIAMETER (mm)	53	44	49	40	61
PENETRATION (mm)	8	8	10	16	11

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 1·59 mm/μs

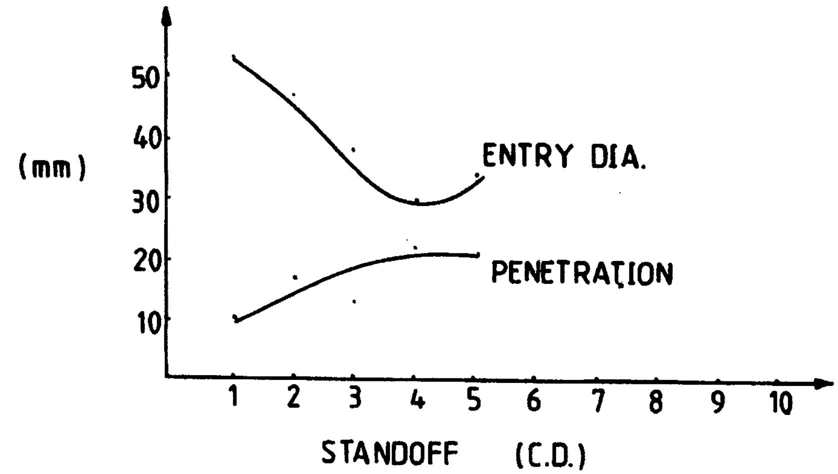


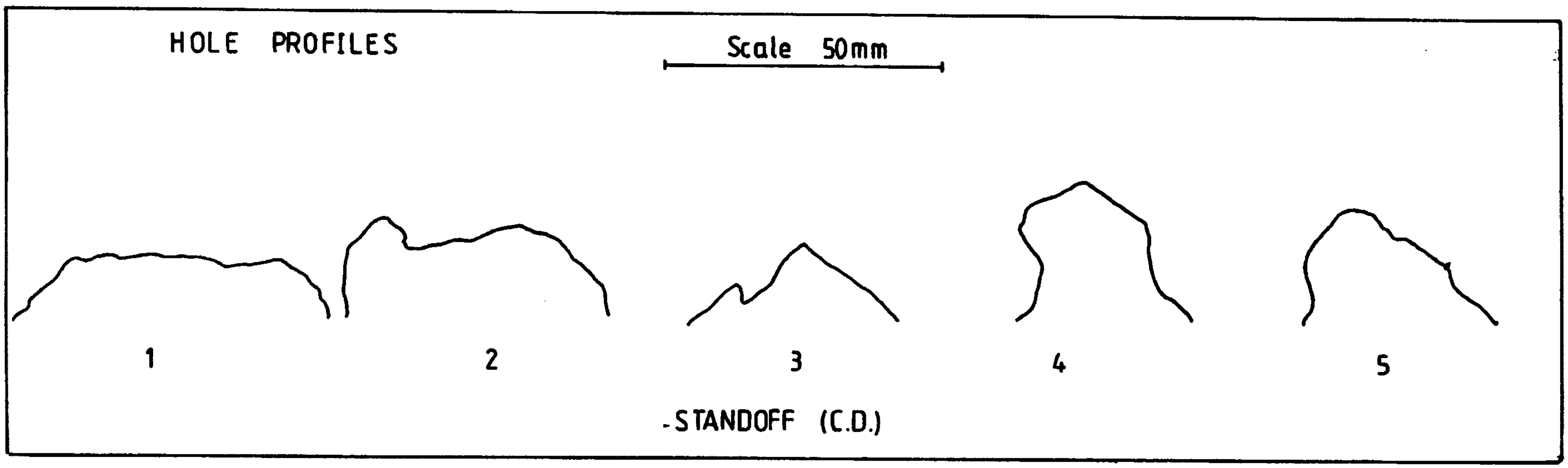


R 60 x Ø60mm x 3·3mm ZIRCONIUM

STANDOFF (C.D.)	1	2	3	4	5
ENTRY DIAMETER (mm)	53	47	38	30	34
PENETRATION (mm)	10	17	13	22	21

CHARGE FILLED TO 1/2 C.D. HEAD HEIGHT
ALUMINIUM CASE
J.T.V. = 2·04 mm/μs





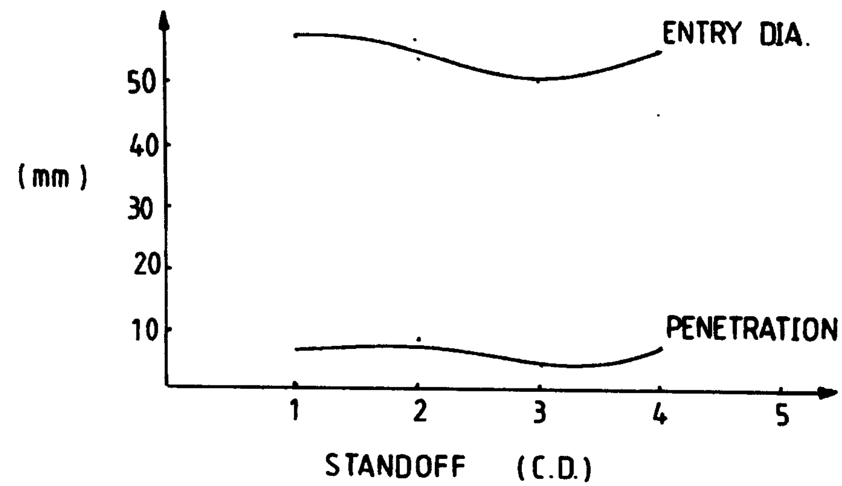
Φ 60 x R40 x 4mm MAGNESIUM (SHEET)

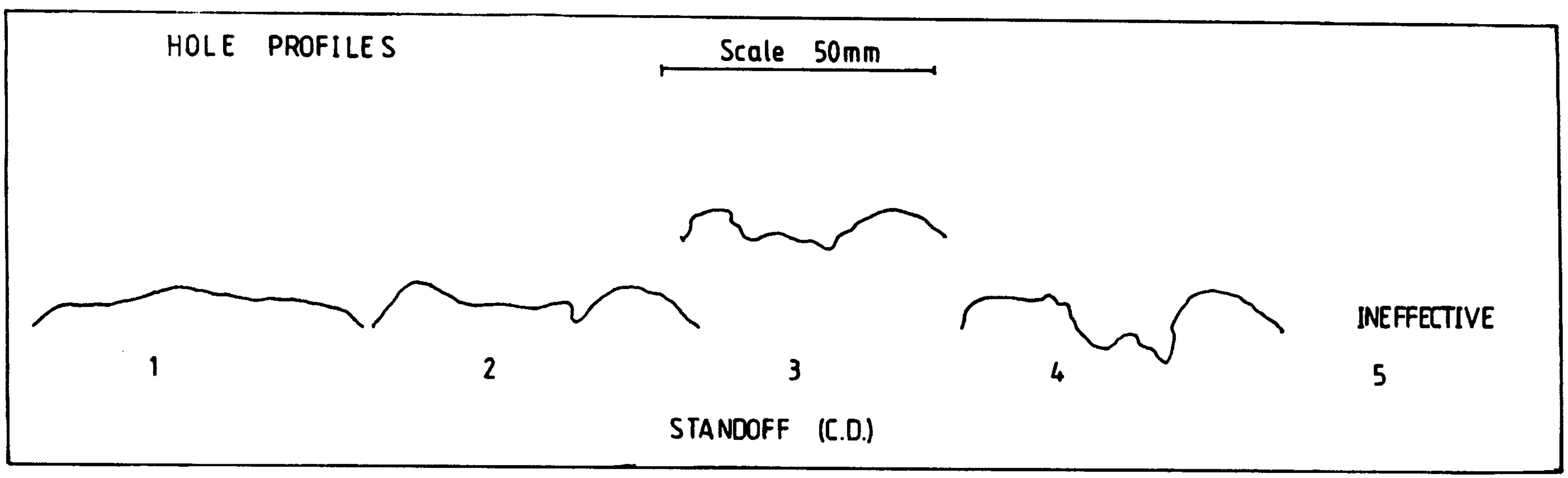
STANDOFF (C.D.)	1	2	3	4	5
ENTRY DIAMETER (mm)	57	57	50	55	max.
PENETRATION (mm)	6	8	4	7	min.

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 3·13 mm/μs





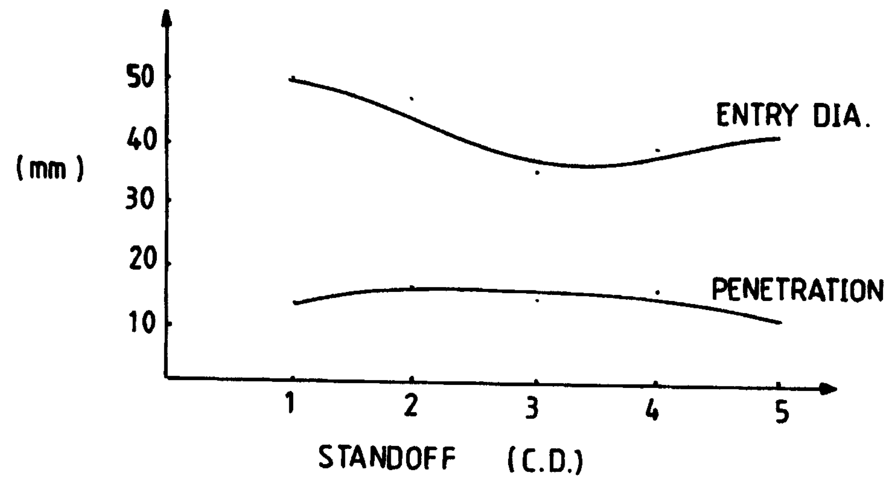
ϕ 60 x R40 x 4 mm ALUMINIUM

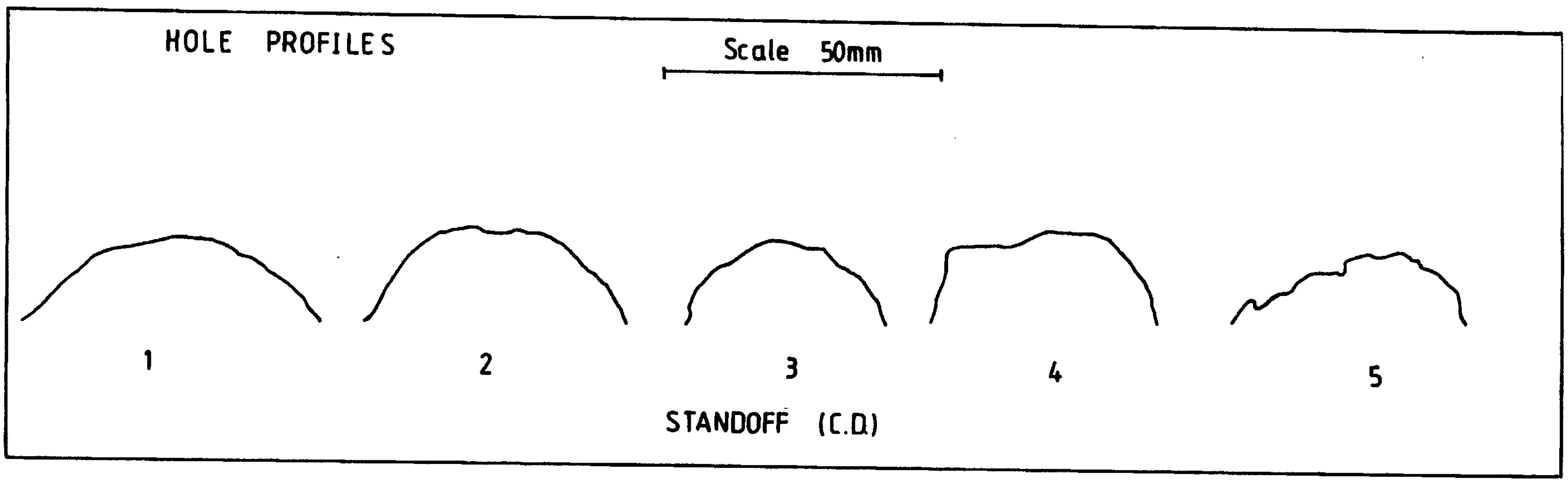
STANDOFF (C.D.)	1	2	3	4	5
ENTRY DIAMETER (mm)	50	47	35	39	41
PENETRATION (mm)	13	16	14	16	11

CHARGE FILLED TO 1/3 C.D. HEAD HEIGHT

ALUMINIUM CASE

J.T.V. = 2·56 mm / μs

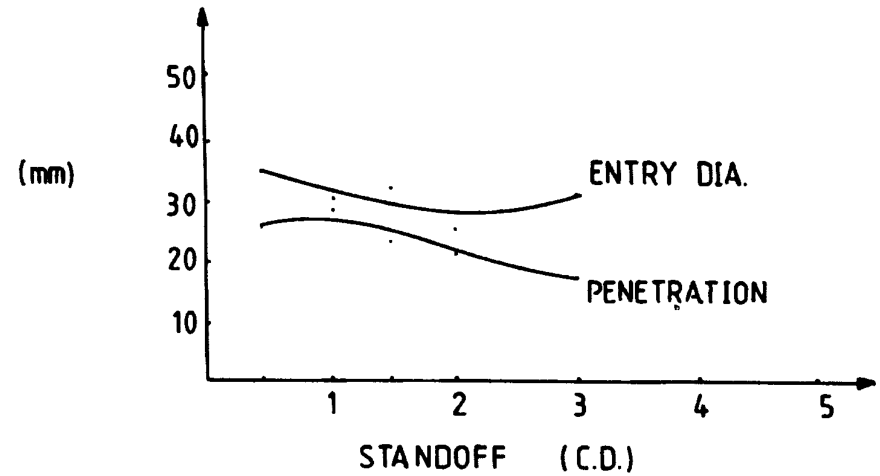


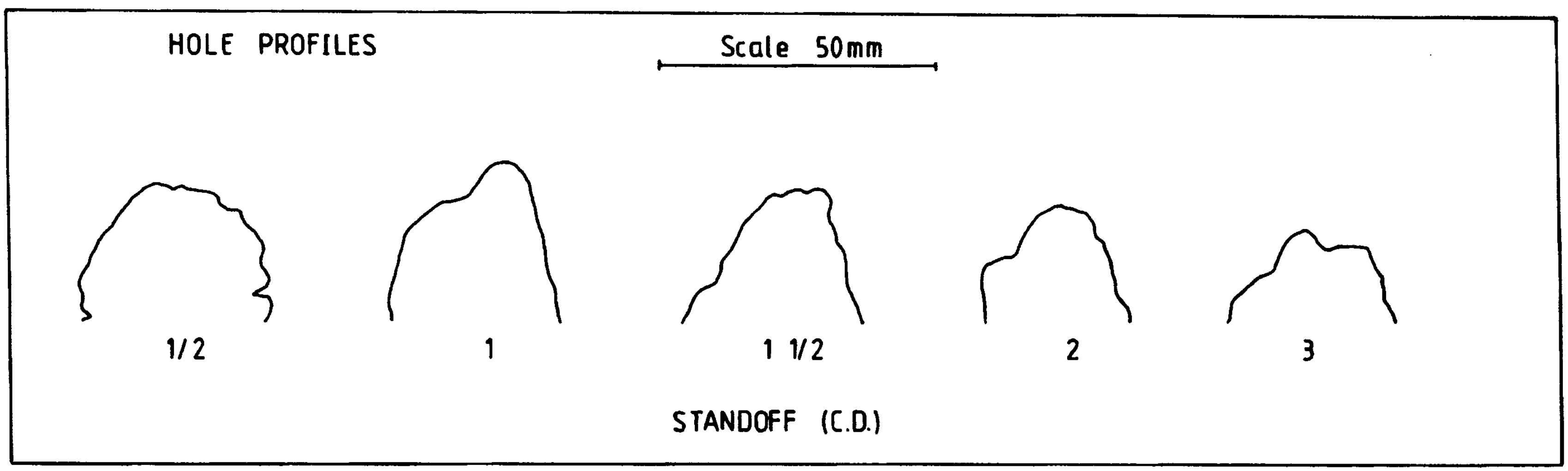


ϕ 38mm x 90° TEFLON

STANDOFF (C.D)	1/2	1	1 1/2	2	3
ENTRY DIAMETER (mm)	34	30	32	25	31
PENETRATION (mm)	25	28	23	21	17

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK





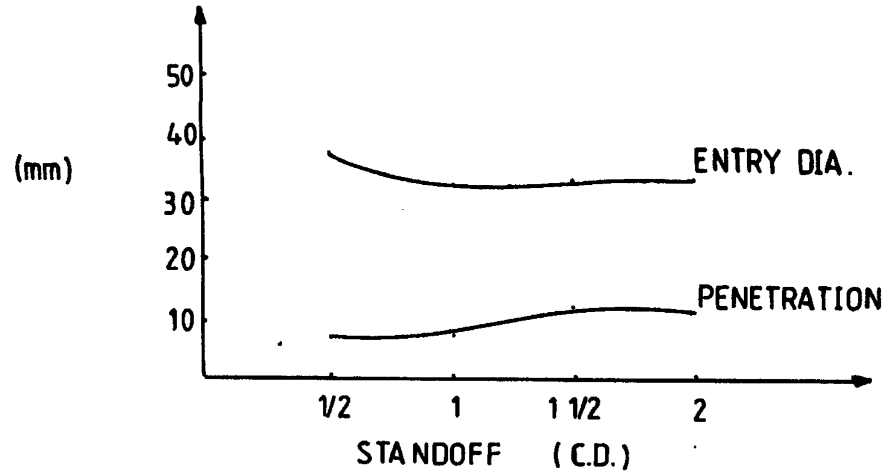
ϕ 38 mm x R40 TEFLON

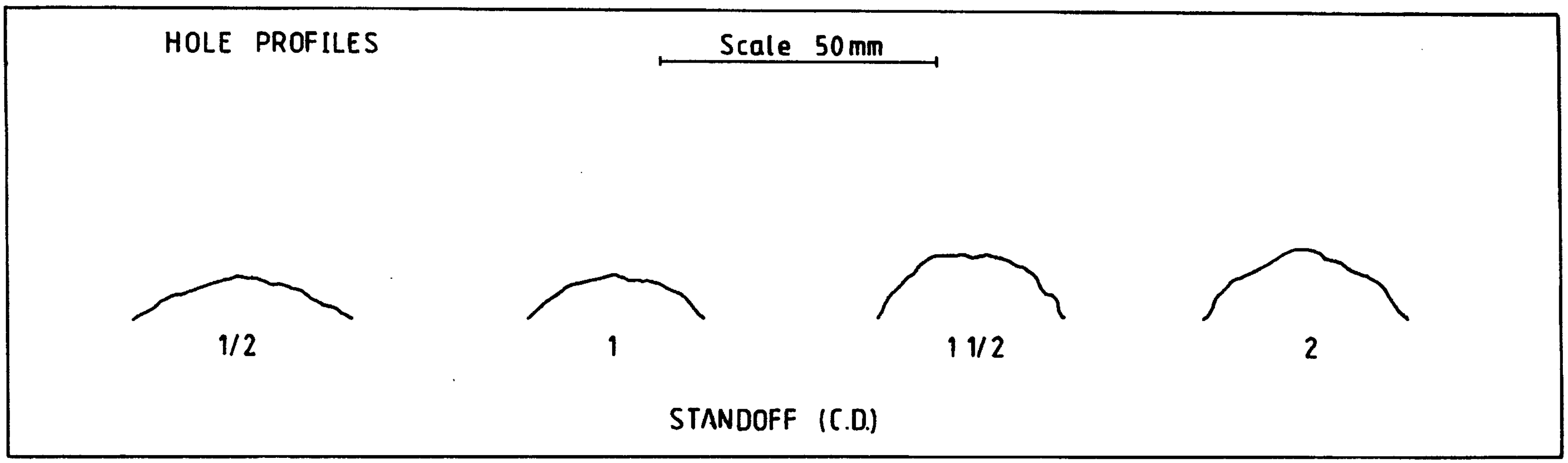
STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)	37	32	33	33
PENETRATION (mm)	7	7	12	11

CHARGE FILLED TO 66 mm HEAD HEIGHT

ALUMINIUM CASE

LINER 1mm THICK

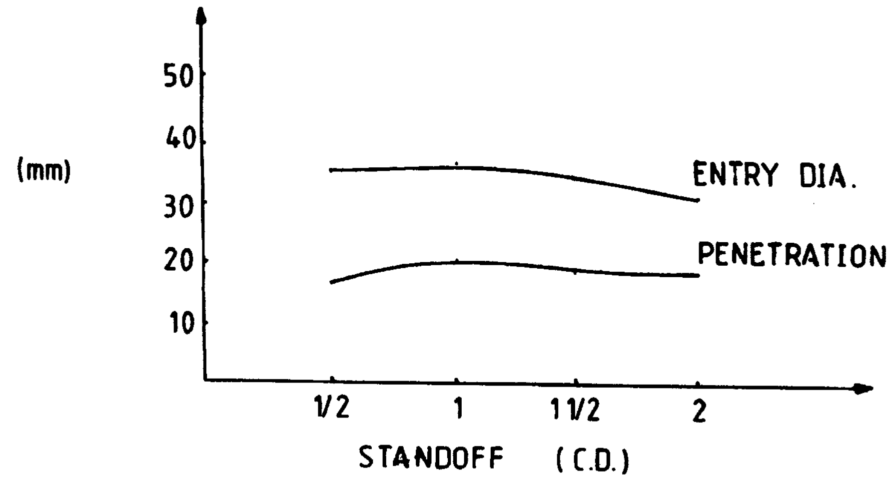


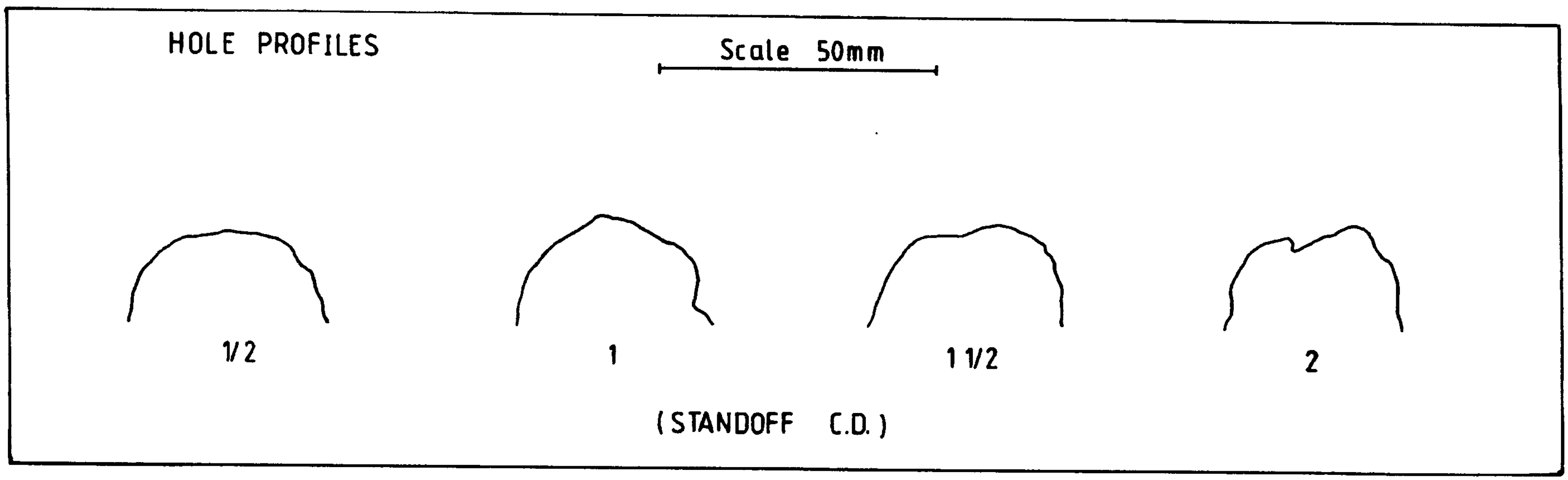


Φ 38 mm x 90° NYLON

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)	35	36	34	31
PENETRATION (mm)	16	20	18	18

CHARGE FILLED TO 52 mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK

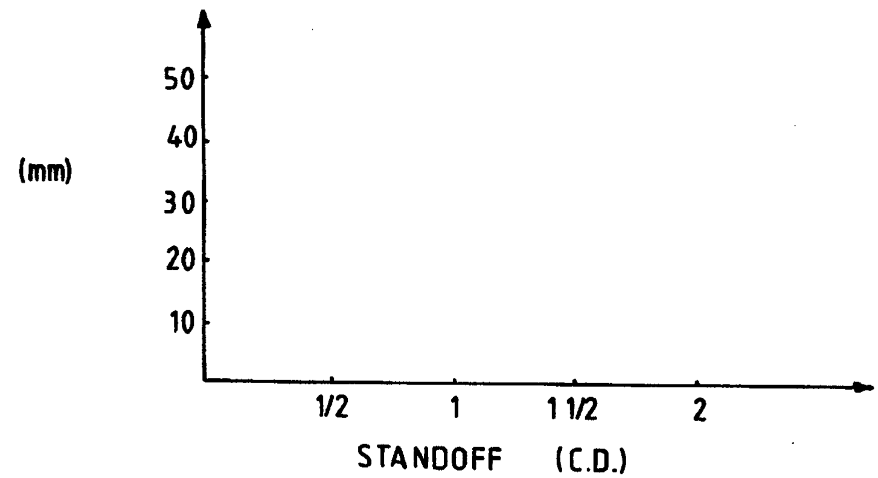


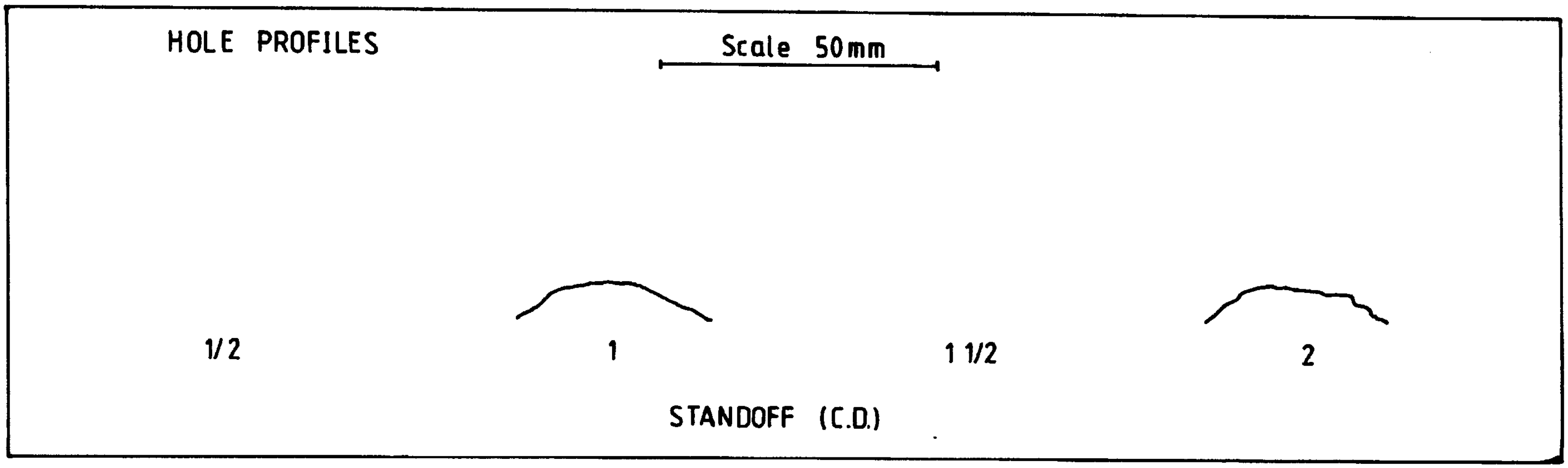


Φ 38mm x R40 NYLON

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)		33		32
PENETRATION (mm)		7		6

CHARGE FILLED TO 66 mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK

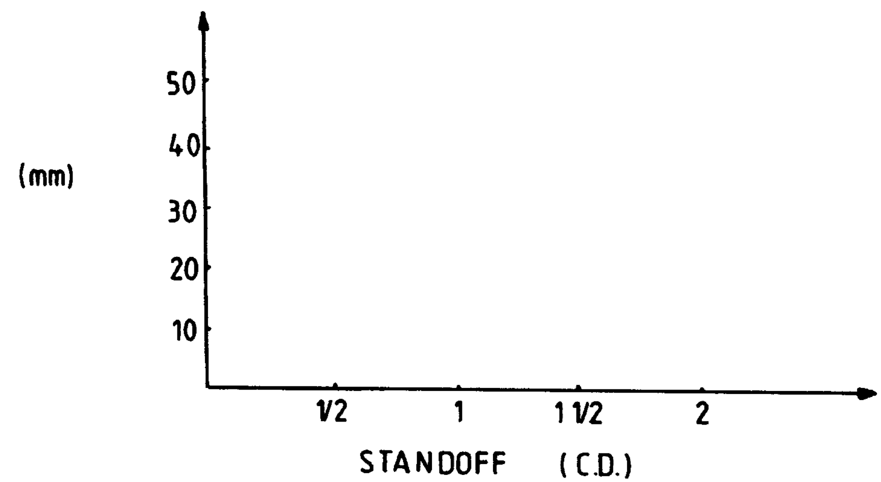


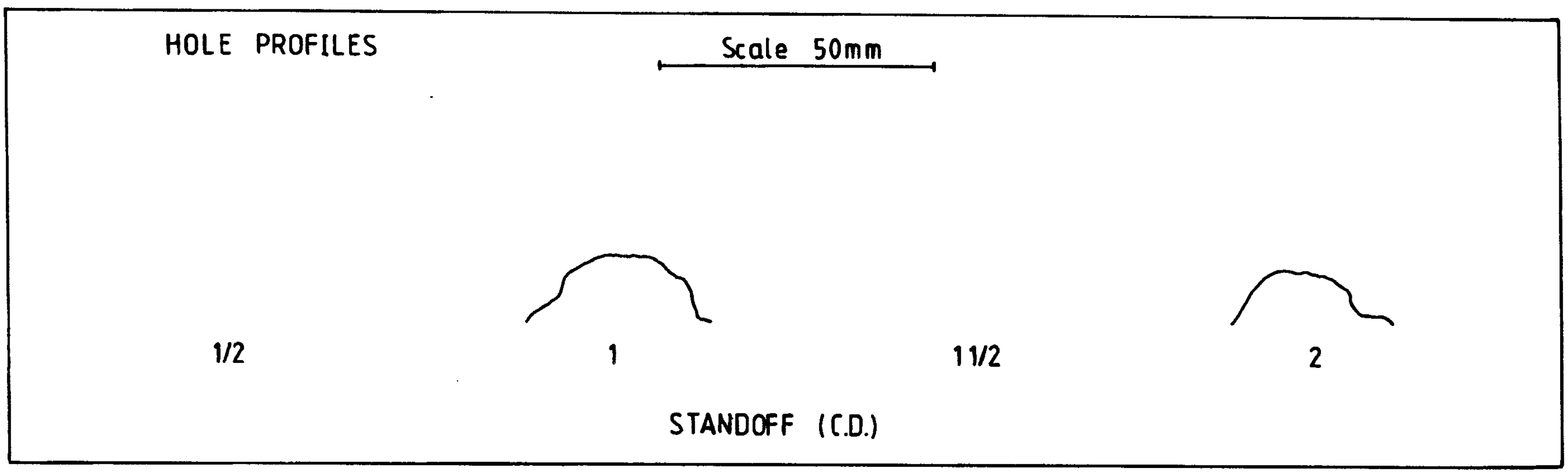


ϕ 38mm x 140° NYLON

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)		31		28
PENETRATION (mm)		12		9

CHARGE FILLED TO 64mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK





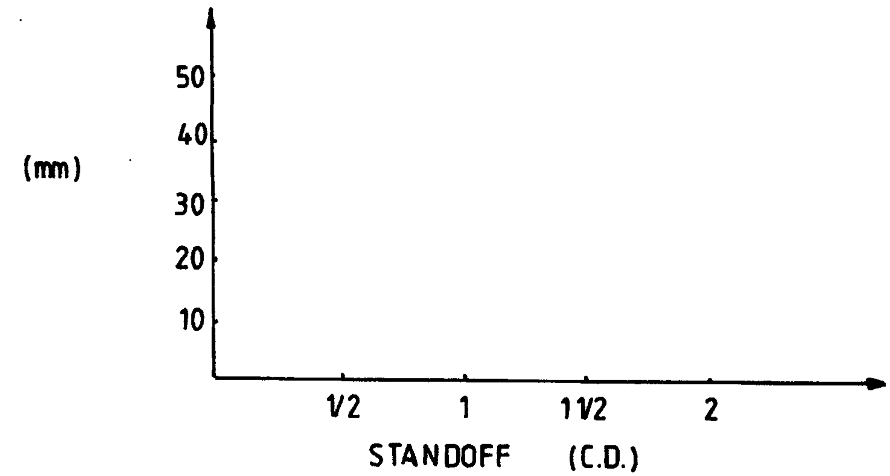
ϕ 38 mm x NYLON HEMI.

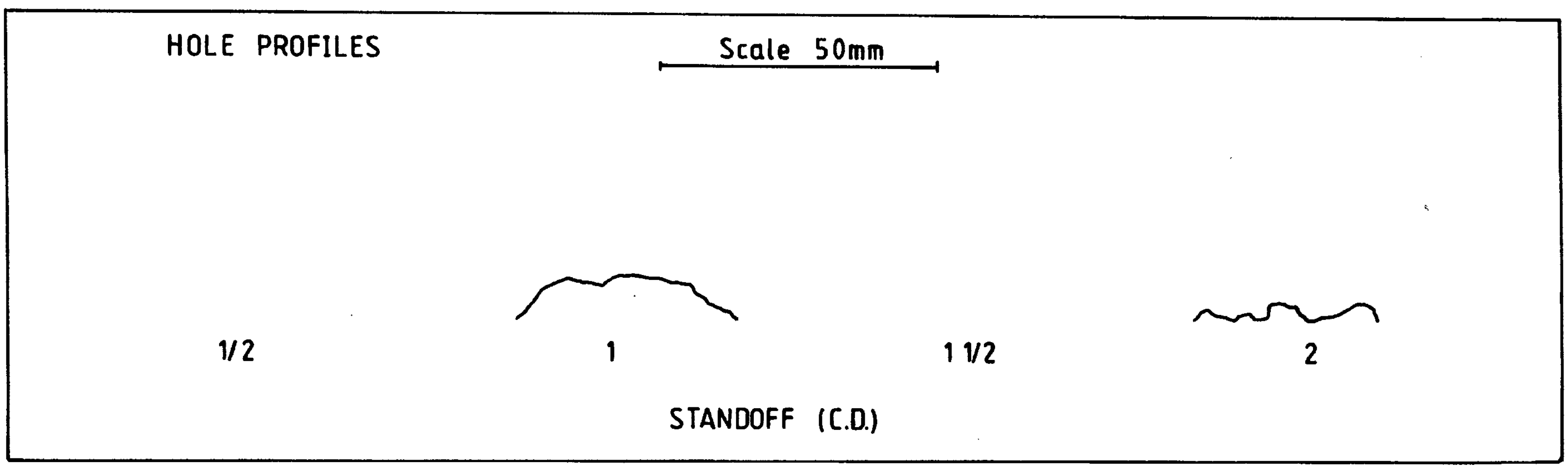
STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)		40		32
PENETRATION (mm)		8		3

CHARGE FILLED TO 52 mm HEAD HEIGHT

ALUMINIUM CASE

LINER 1mm THICK

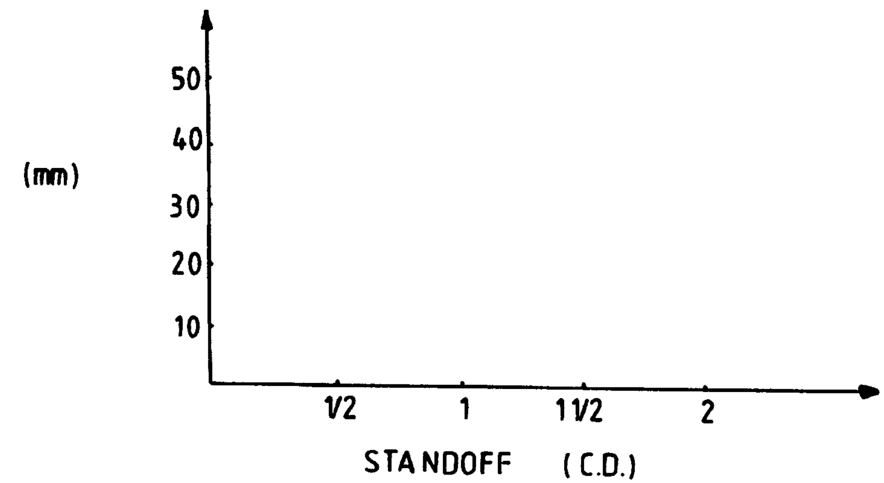


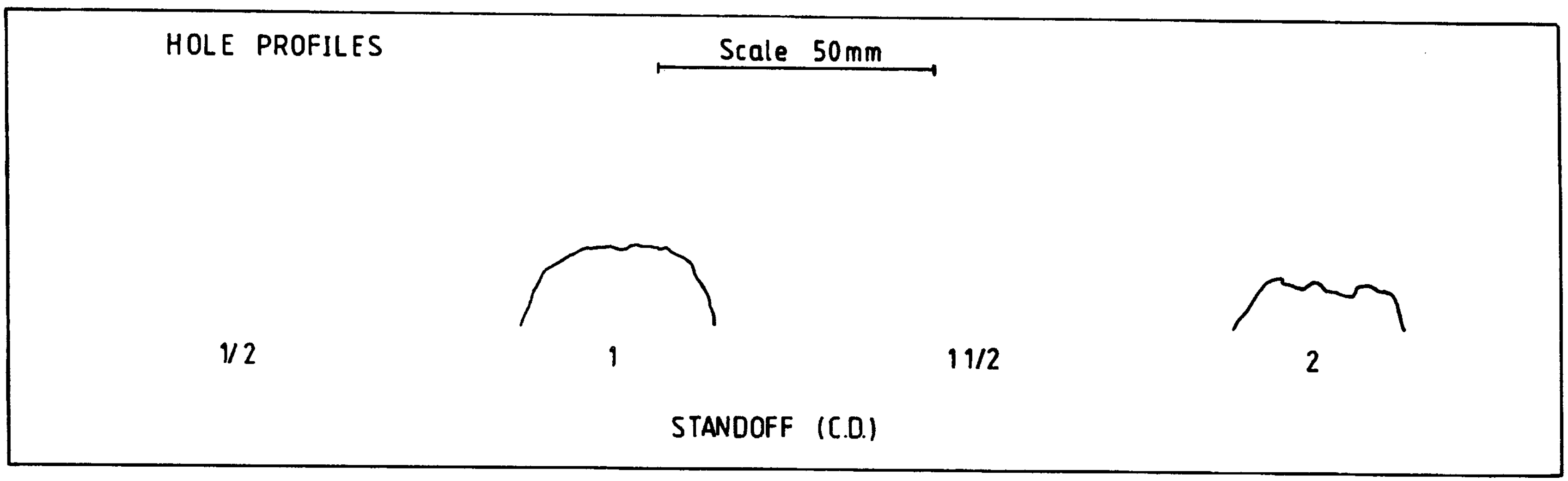


ϕ 38 mm x 90° POLYETHYLENE

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)		35		30
PENETRATION (mm)		14		9

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK

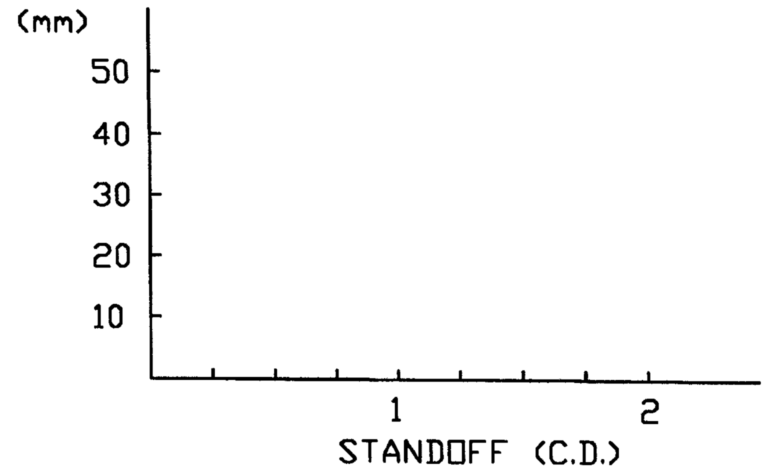


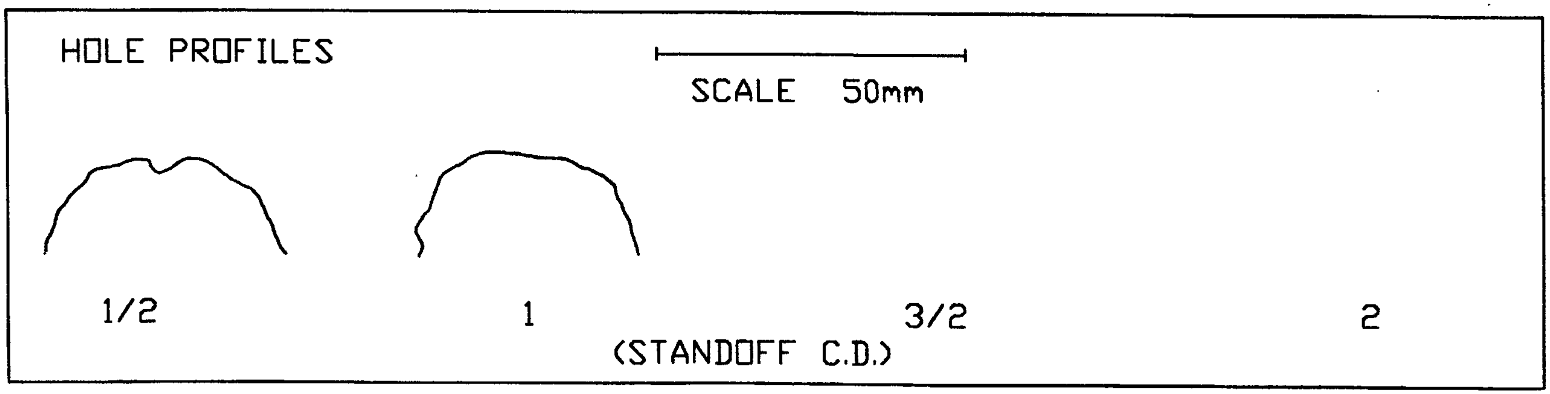


Ø38 × 90° POLYETHYLENE

STANDOFF (C.D.)	1/2	1	3/2	2
ENTRY DIAMETER (mm)	38	34		
PENETRATION (mm)	15	16		

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 2mm THICK

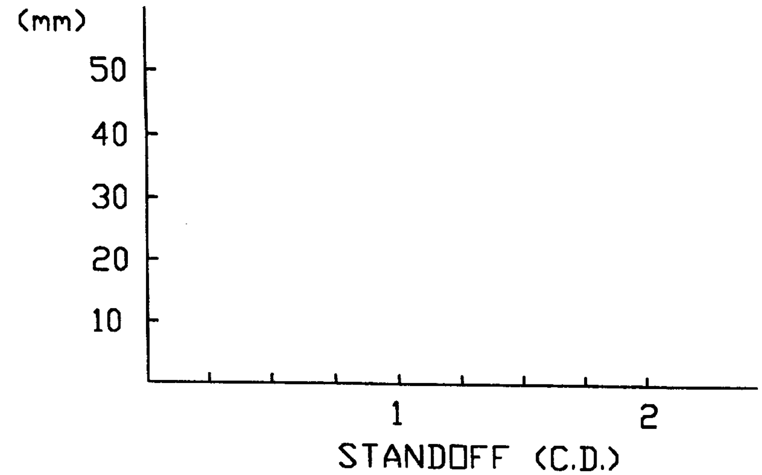


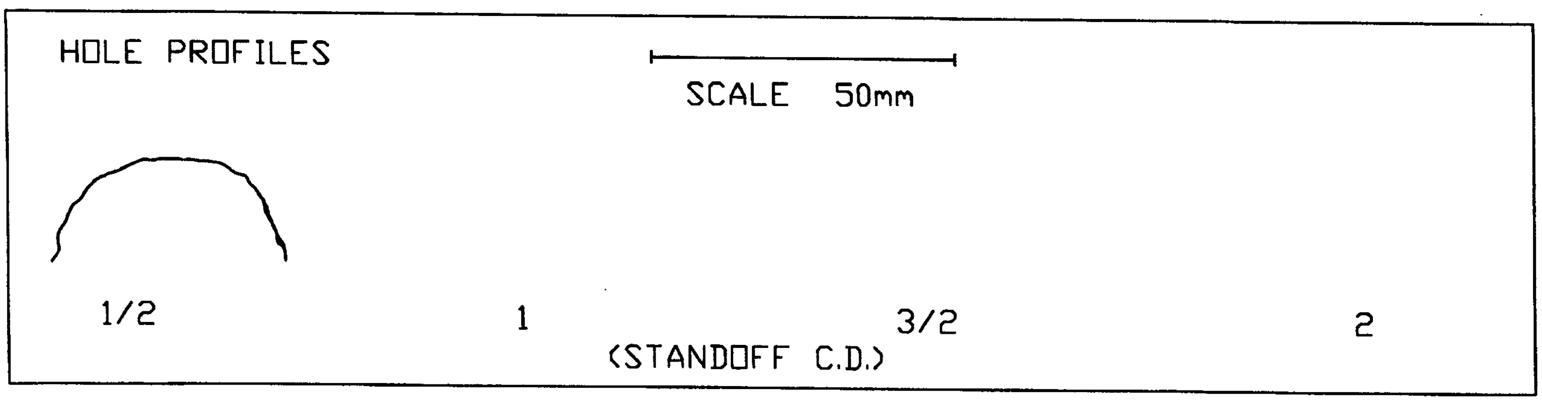


Ø38 x 90° POLYETHYLENE

STANDOFF (C.D.)	1/2	1	3/2	2
ENTRY DIAMETER (mm)	37			
PENETRATION (mm)	15			

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 3mm THICK

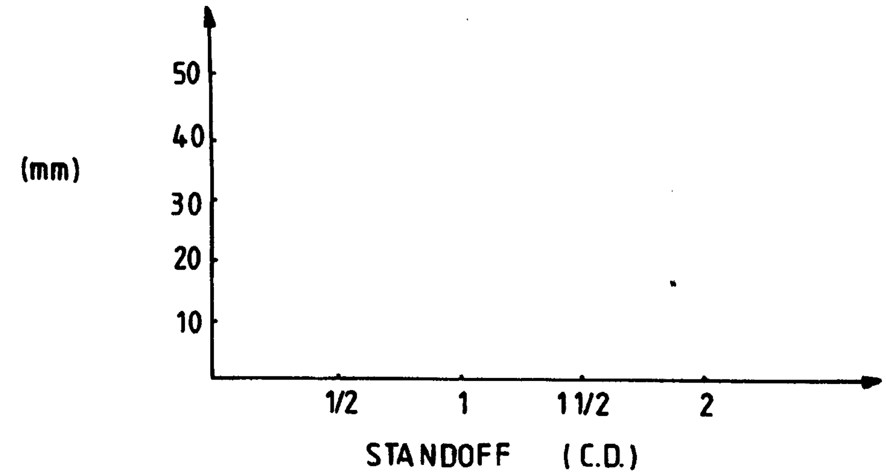


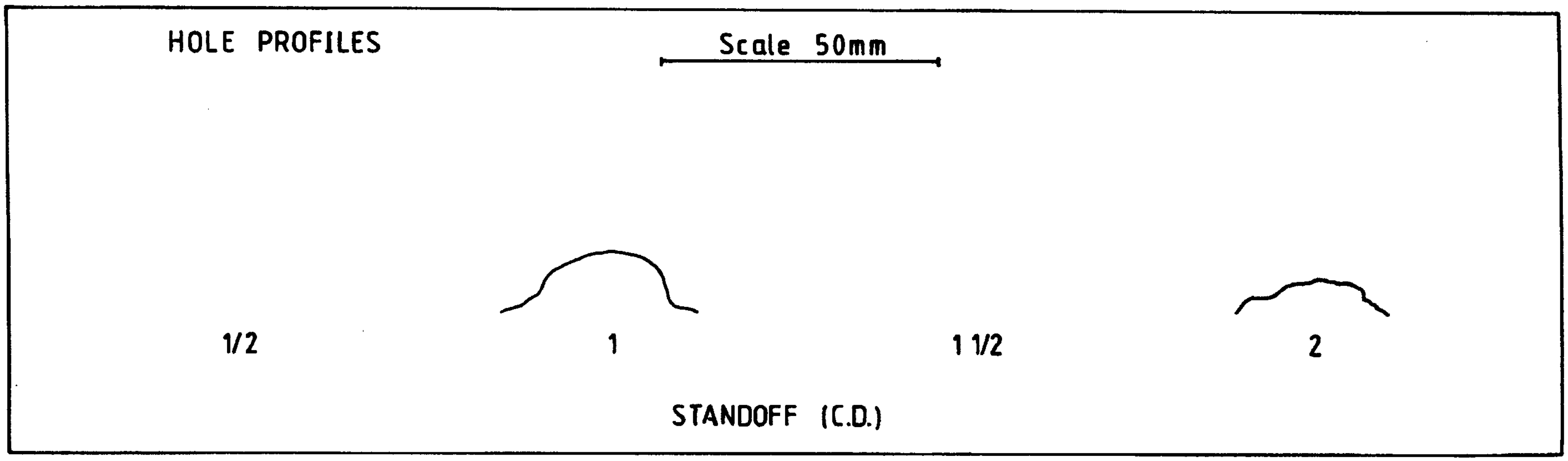


ϕ 38mm x 140° POLYETHYLENE

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)		31		26
PENETRATION (mm)		11		6

CHARGE FILLED TO 64mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK

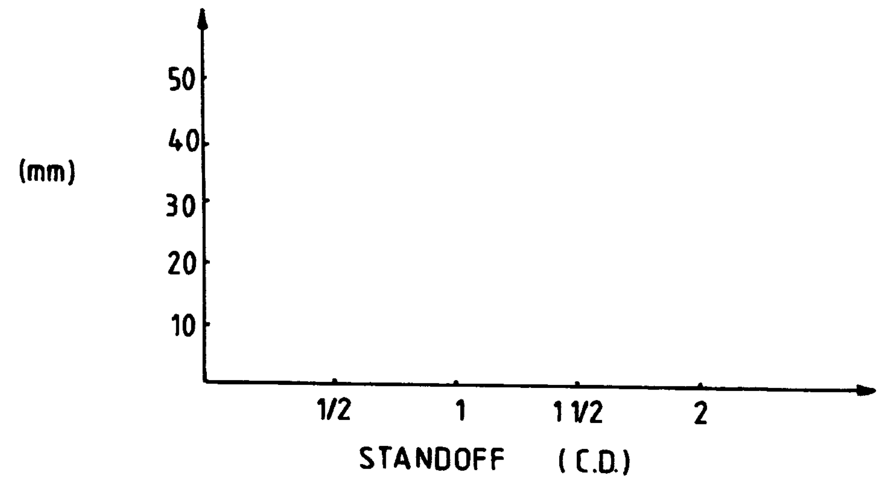


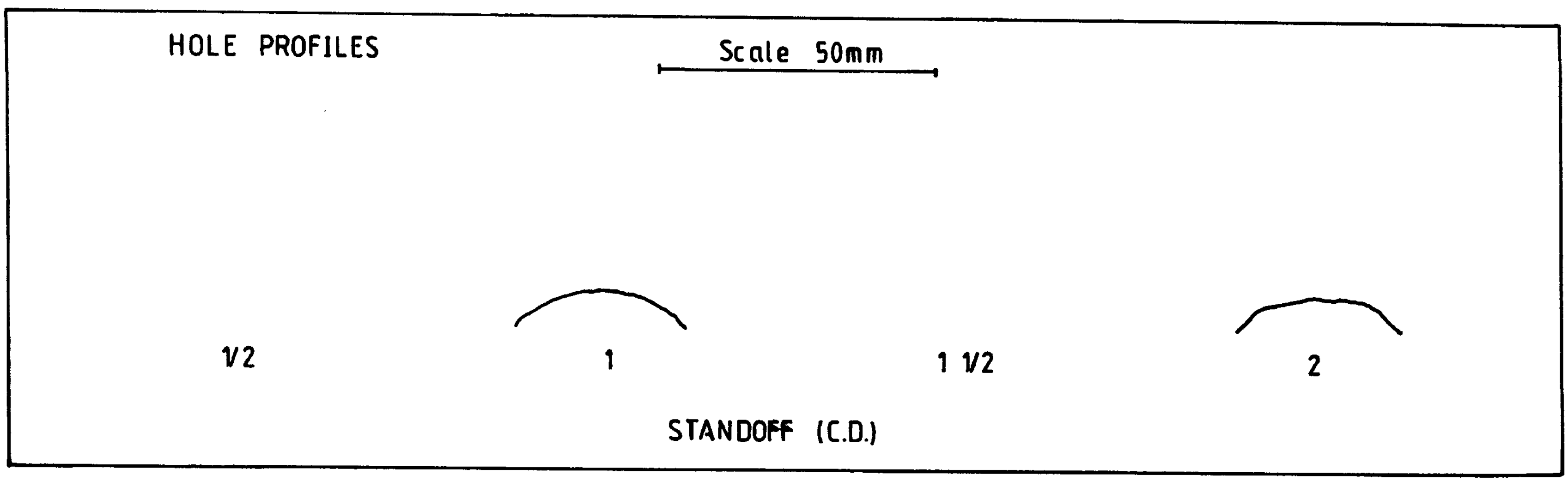


Φ 38 mm x R40 POLYETHYLENE

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)		32		30
PENETRATION (mm)		7		6

CHARGE FILLED TO 66 mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK

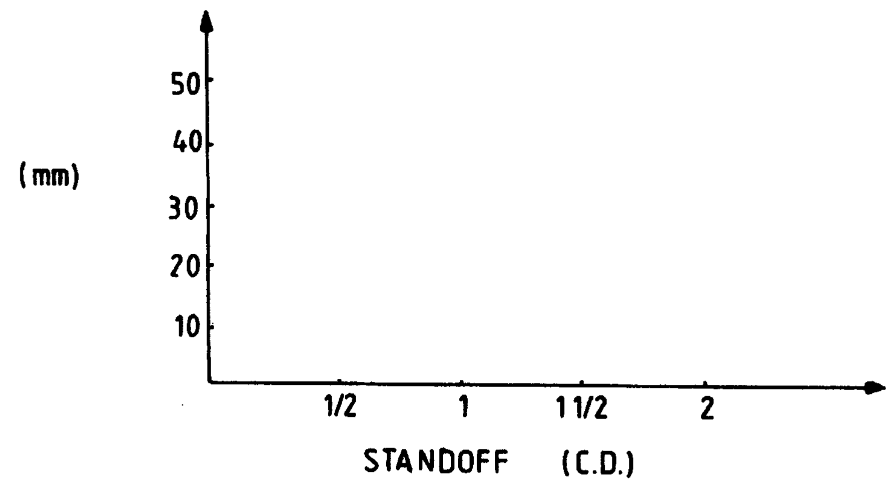


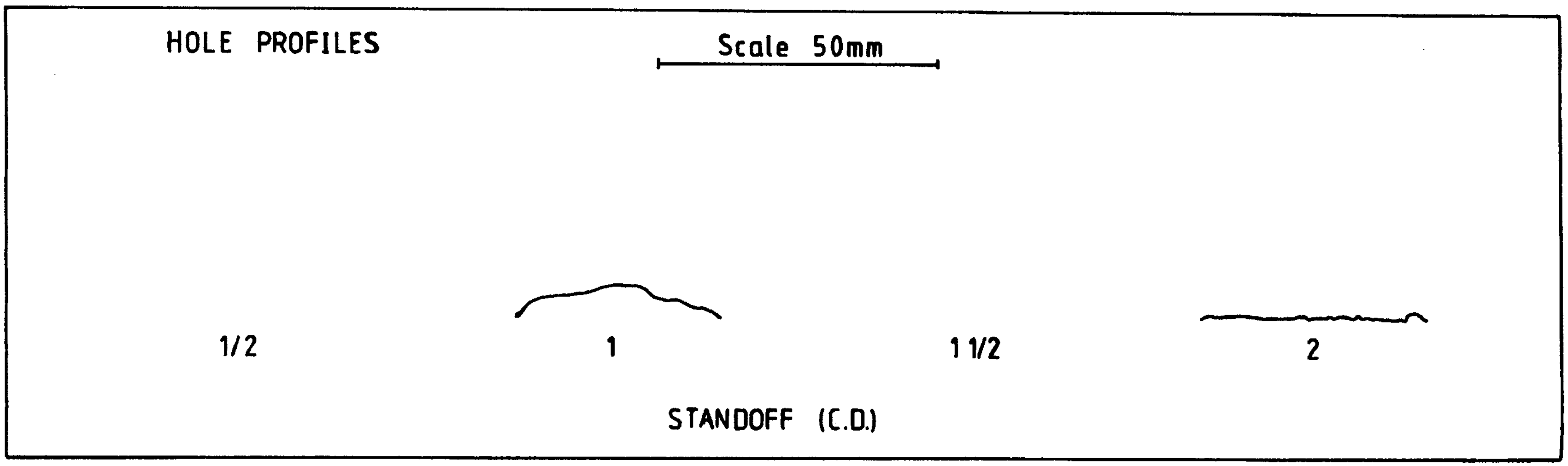


Ø 38 mm x POLYETHYLENE HEMI.

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)		37		40
PENETRATION (mm)		6		2

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK

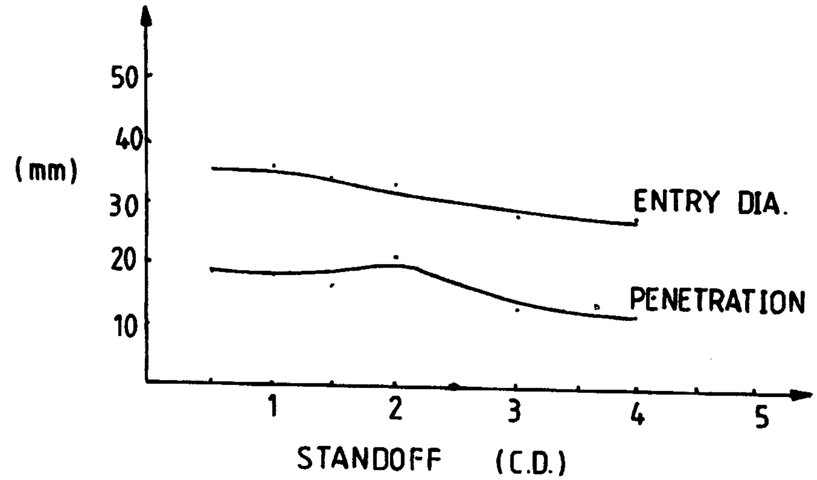


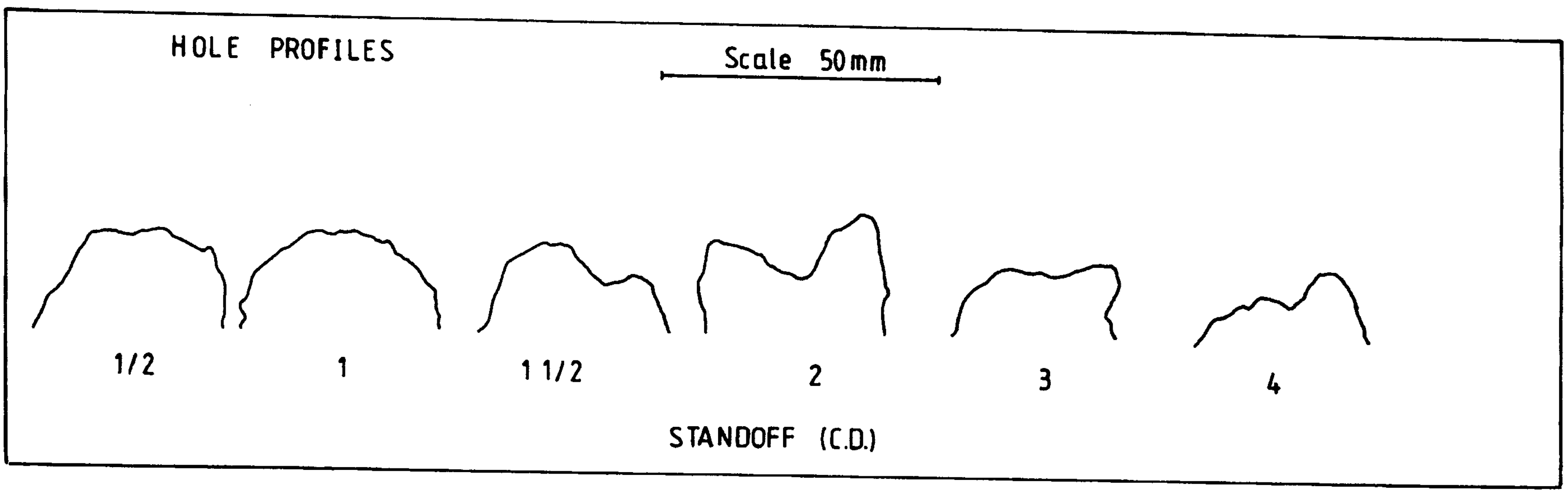


ϕ 38 mm x 90° PVC

STANDOFF (C.D.)	1/2	1	1 1/2	2	3	4
ENTRY DIAMETER (mm)	35	36	34	33	28	28
PENETRATION (mm)	18	18	16	21	13	12

CHARGE FILLED TO 52 mm HEAD HEIGHT
ALUMINIUM CASE
PVC 1 mm THICK

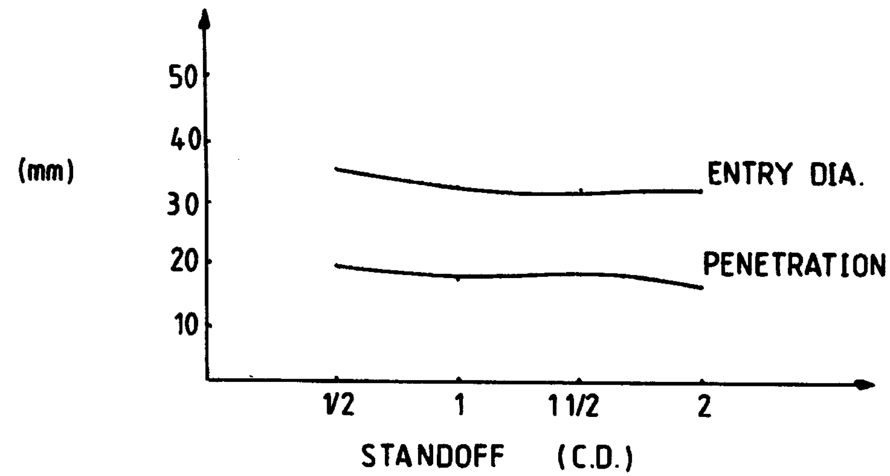


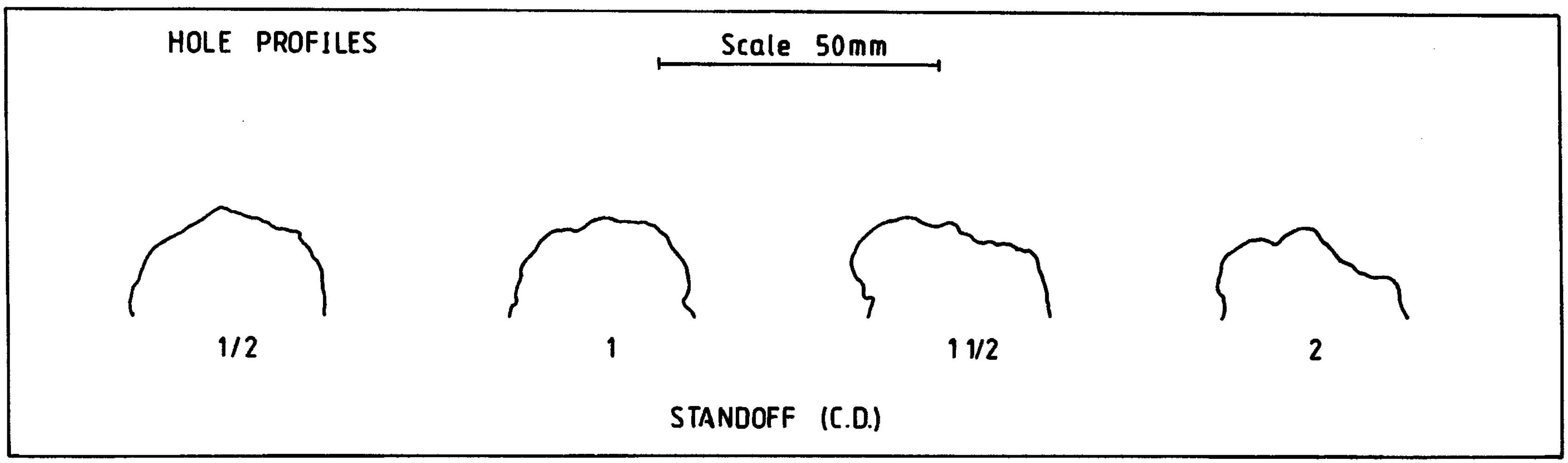


ϕ 38mm x 90° PVC

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)	35	32	32	32
PENETRATION (mm)	19	17	18	16

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
PVC 2mm THICK

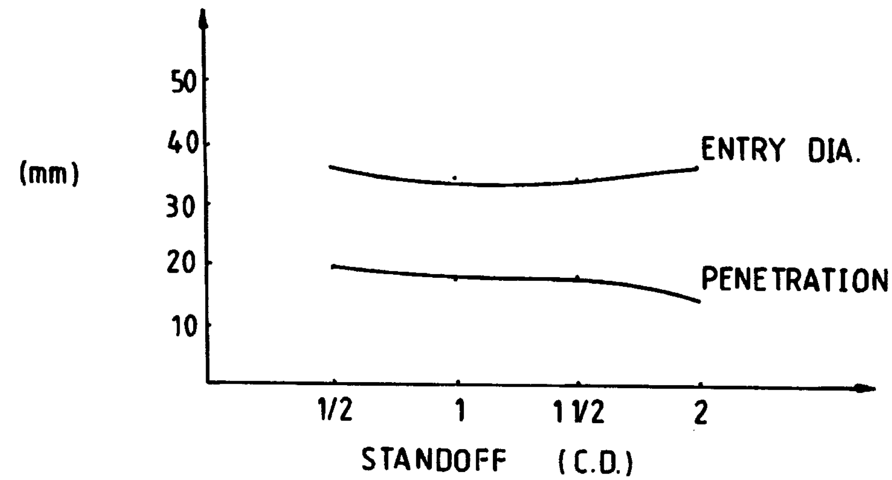


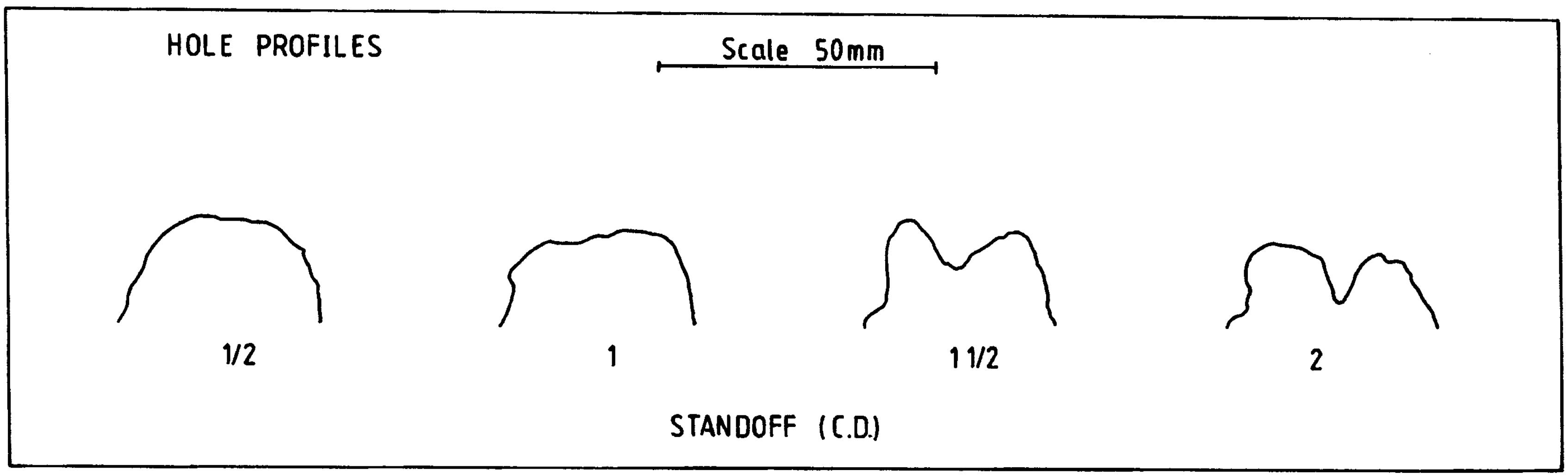


ϕ 38 mm x 90° PVC

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)	36	34	34	36
PENETRATION (mm)	19	17	18	14

CHARGE FILLED TO 52 mm HEAD HEIGHT
ALUMINIUM CASE
PVC 3 mm THICK

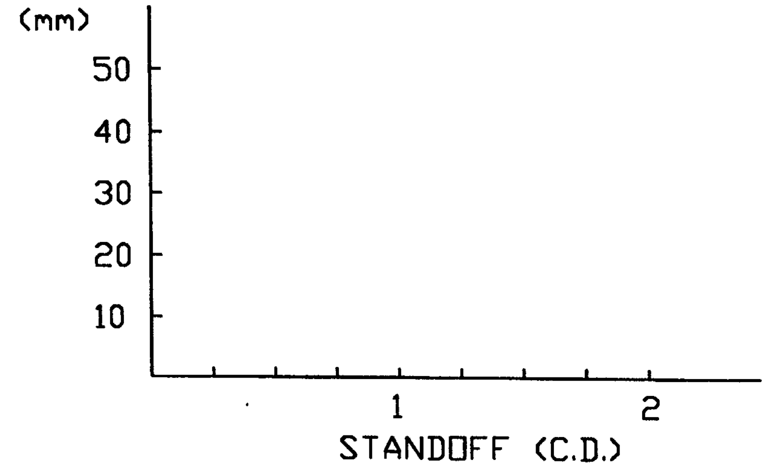


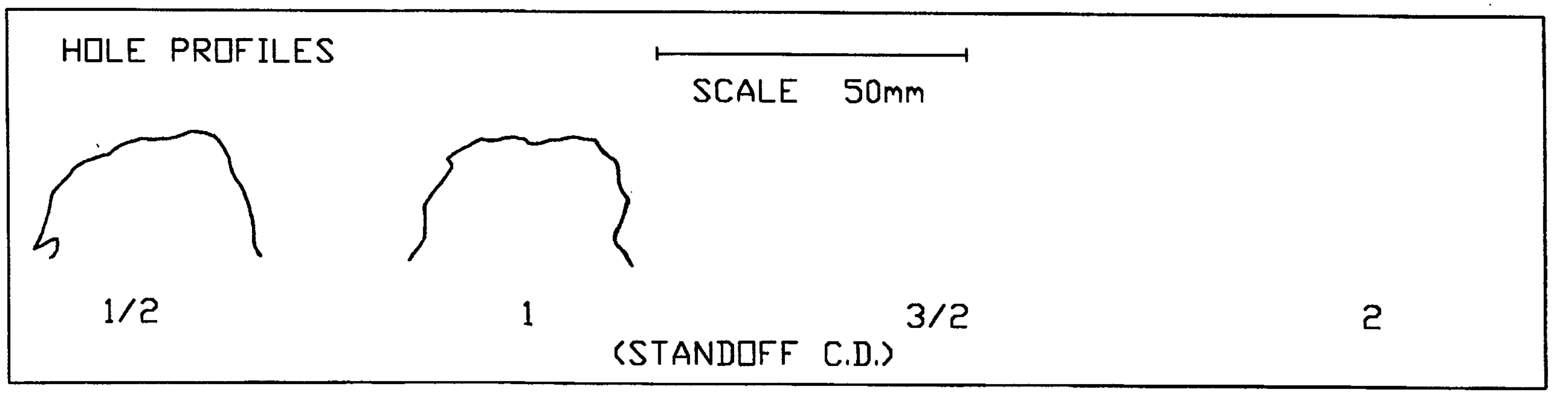


Ø38 × 90° PVC

STANDOFF (C.D.)	1/2	1	3/2	2
ENTRY DIAMETER (mm)	35	34		
PENETRATION (mm)	15	20		

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 4mm THICK

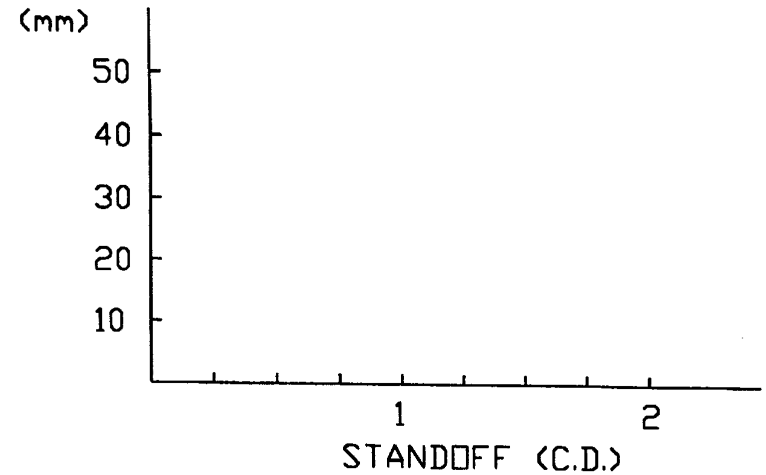


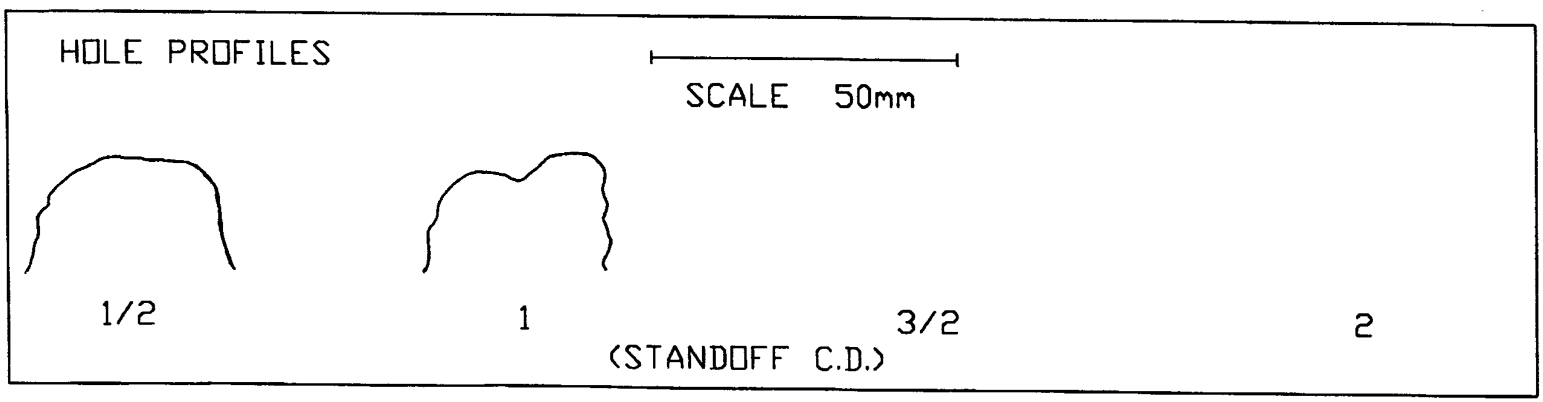


Ø38 x 90° PVC

STANDOFF (C.D.)	1/2	1	3/2	2
ENTRY DIAMETER (mm)	33	29		
PENETRATION (mm)	18	18		

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 5mm THICK

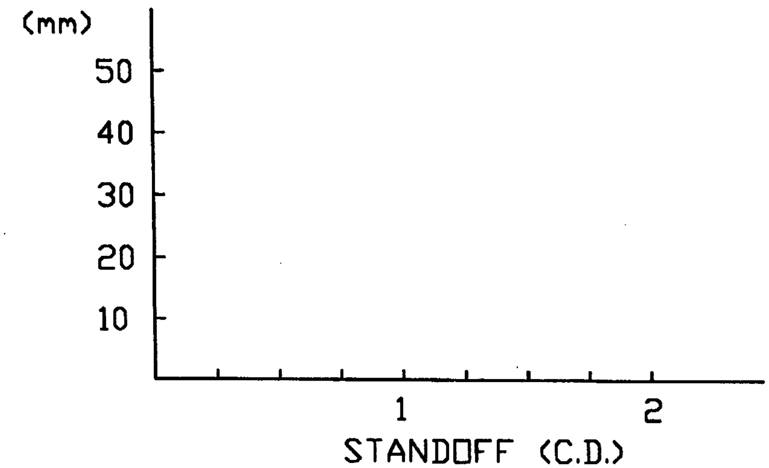


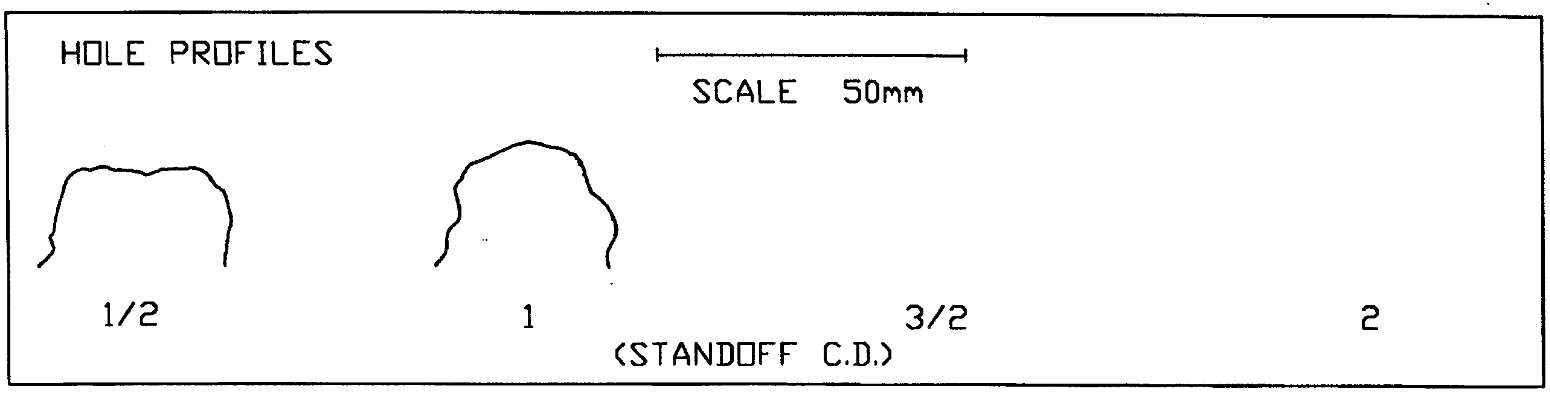


Ø38 x 90° PVC

STANDOFF (C.D.)	1/2	1	3/2	2
ENTRY DIAMETER (mm)	28	28		
PENETRATION (mm)	15	19		

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 6mm THICK

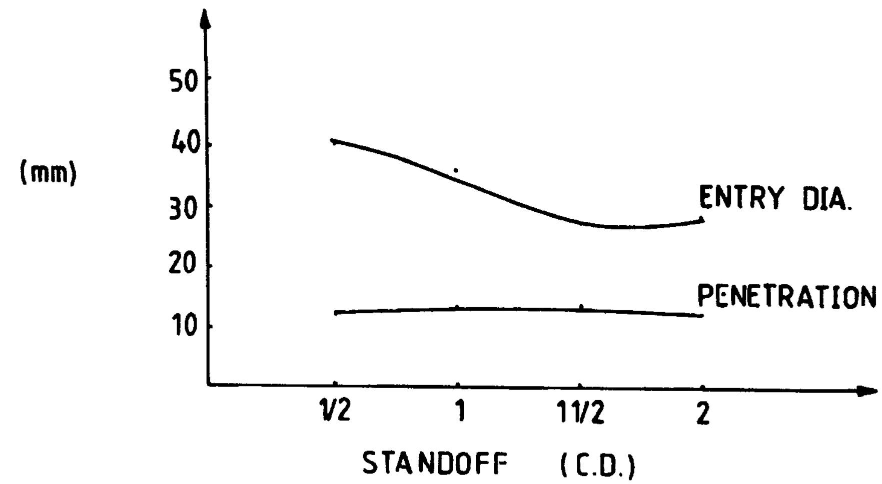


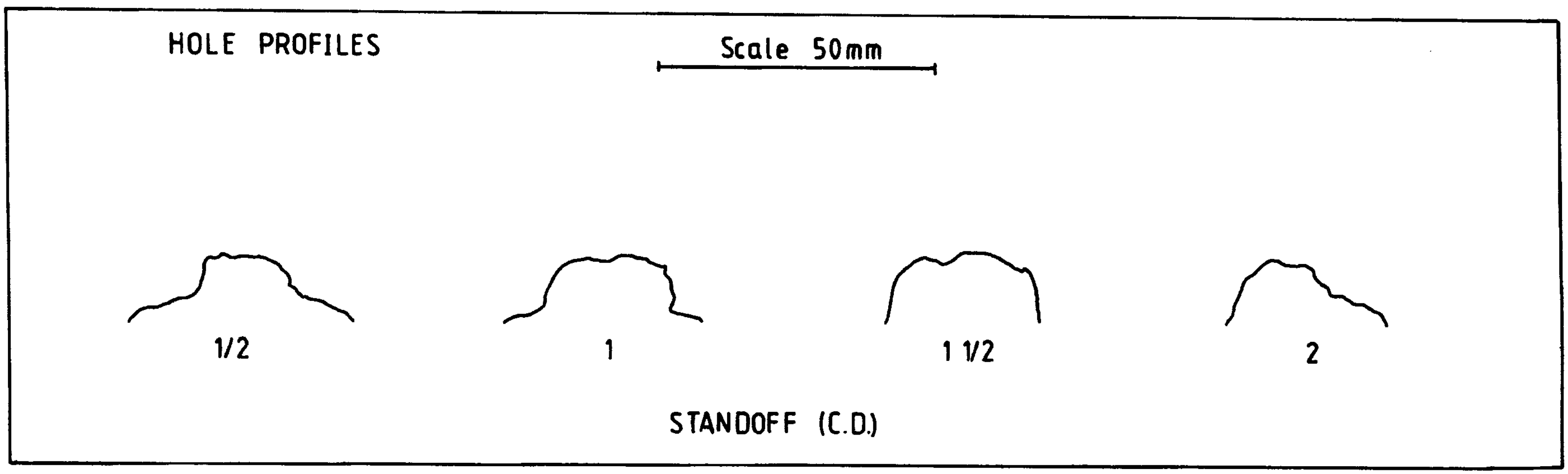


ϕ 38 mm x 140° PVC

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)	40	36	27	28
PENETRATION (mm)	12	13	13	12

CHARGE FILLED TO 64mm HEAD HEIGHT
ALUMINIUM CASE
PVC 1 mm THICK

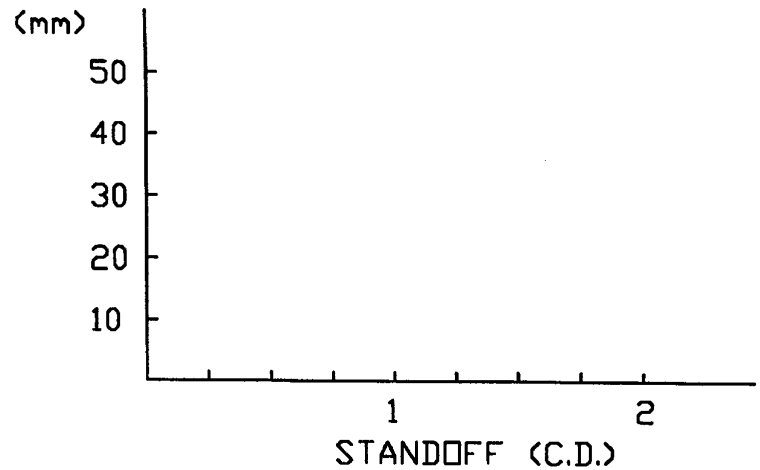


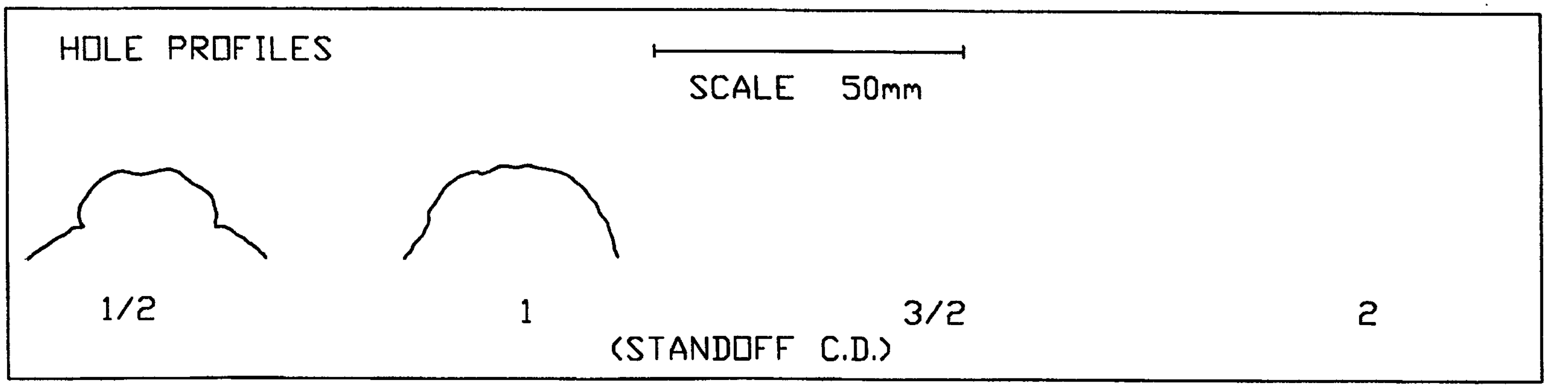


Ø38 x 140° PVC

STANDOFF (C.D.)	1/2	1	3/2	2
ENTRY DIAMETER (mm)	38	34		
PENETRATION (mm)	14	14		

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK

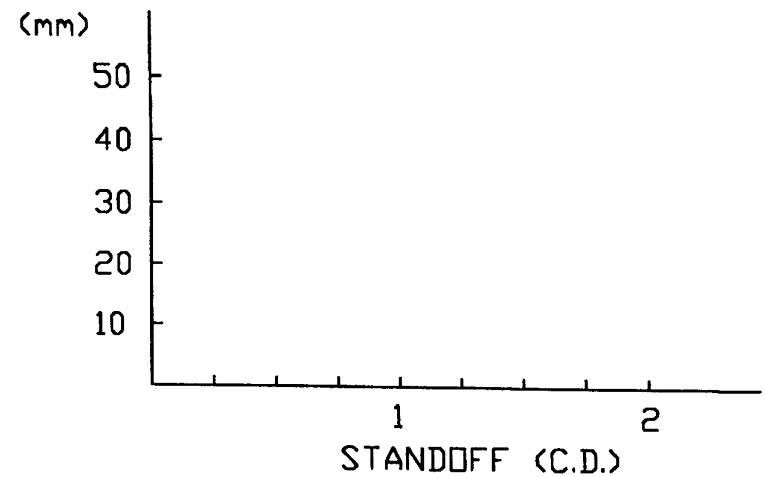


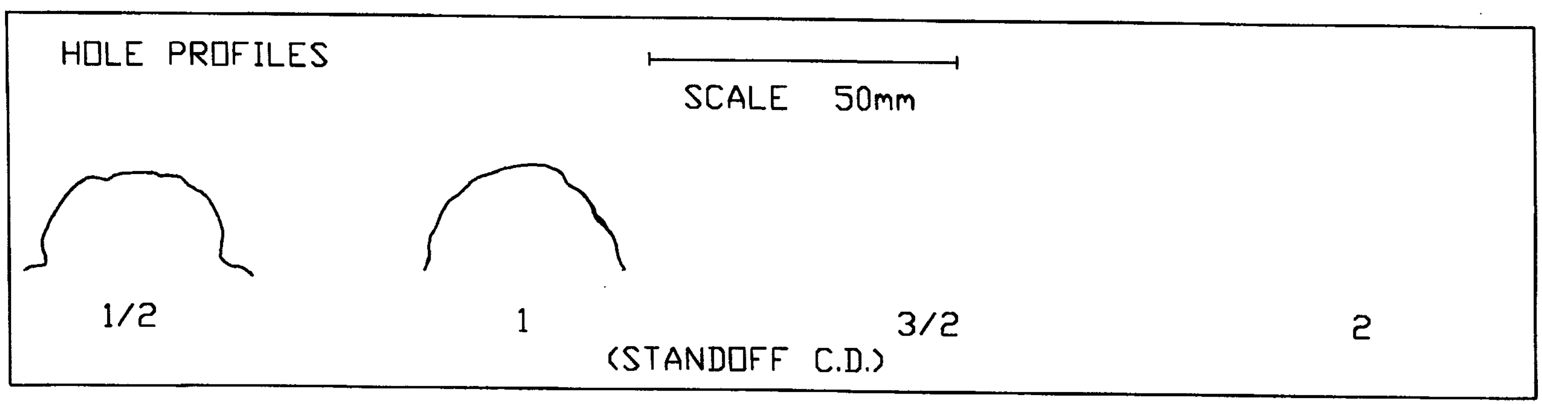


Ø38 x 105° PVC

STANDOFF (C.D.)	1/2	1	3/2	2
ENTRY DIAMETER (mm)	29	32		
PENETRATION (mm)	15	16		

CHARGE FILLED TO 52mm HEAD HEIGHT
ALUMINIUM CASE
LINER 1mm THICK

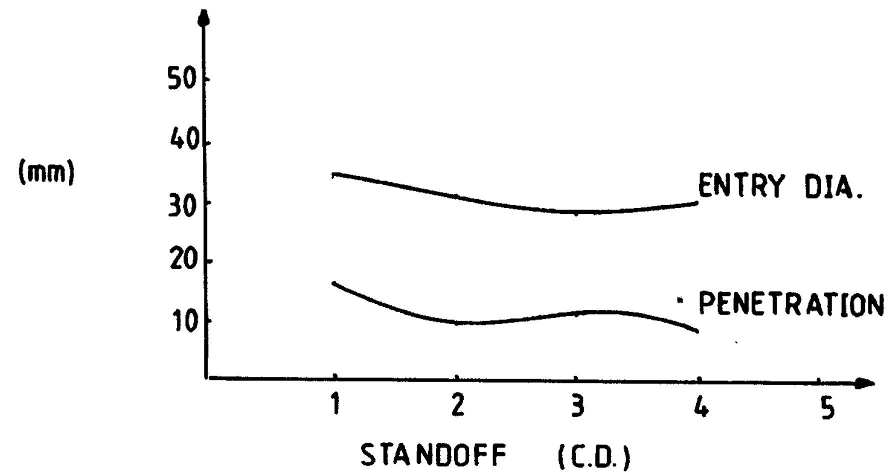


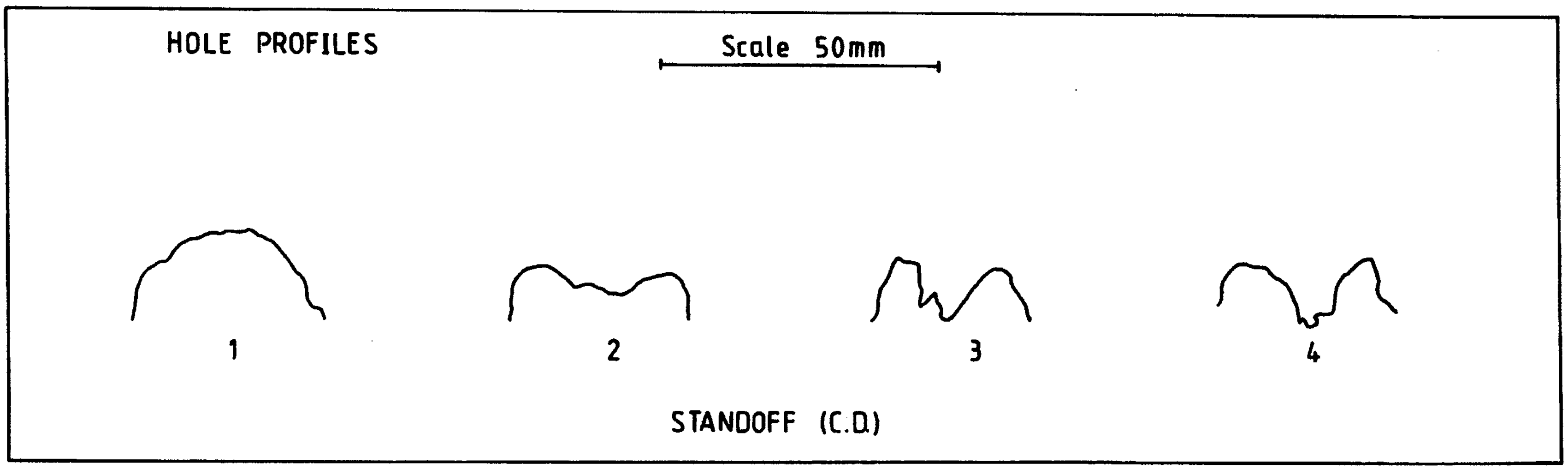


ϕ 38mm x 75° PVC

STANDOFF (C.D.)	1	2	3	4
ENTRY DIAMETER (mm)	34	31	28	30
PENETRATION (mm)	16	9	11	8

CHARGE FILLED TO 46mm HEAD HEIGHT
ALUMINIUM CASE
PVC 1 mm THICK

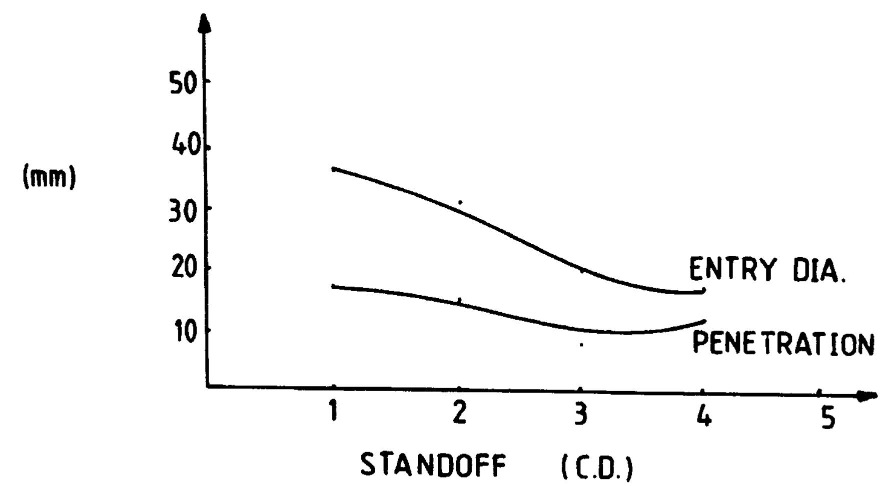


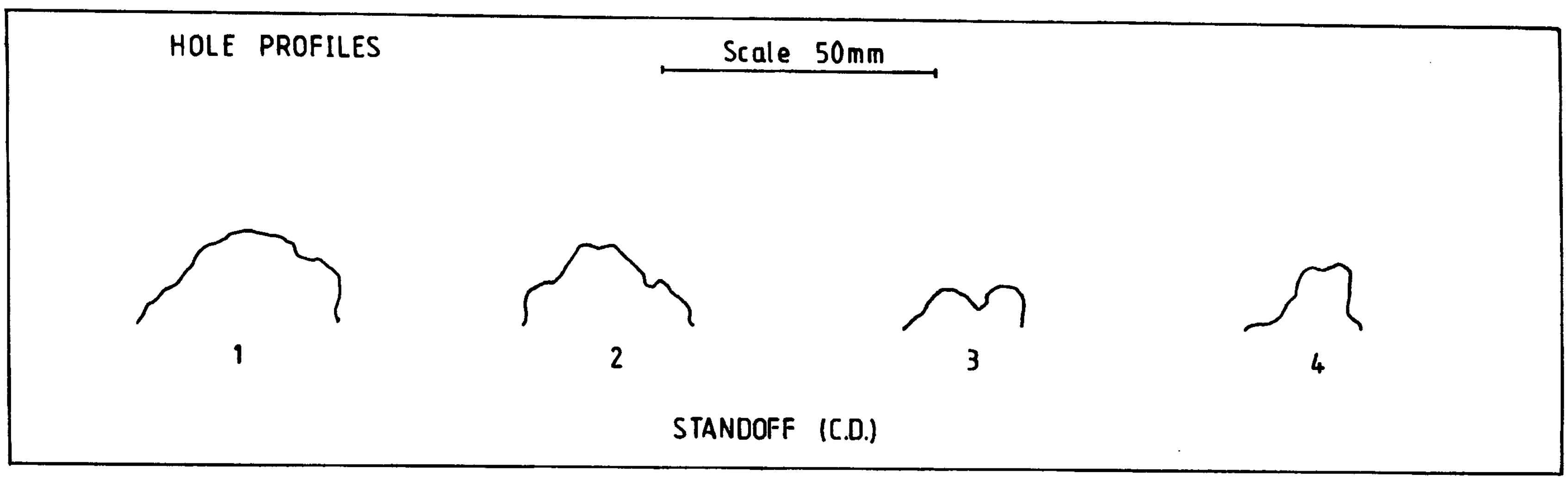


φ 38 mm x 60° PVC

STANDOFF (C.D.)	1	2	3	4
ENTRY DIAMETER (mm)	36	31	20	17
PENETRATION (mm)	17	15	8	12

CHARGE FILLED TO 38 mm HEAD HEIGHT
ALUMINIUM CASE
PVC 1 mm THICK

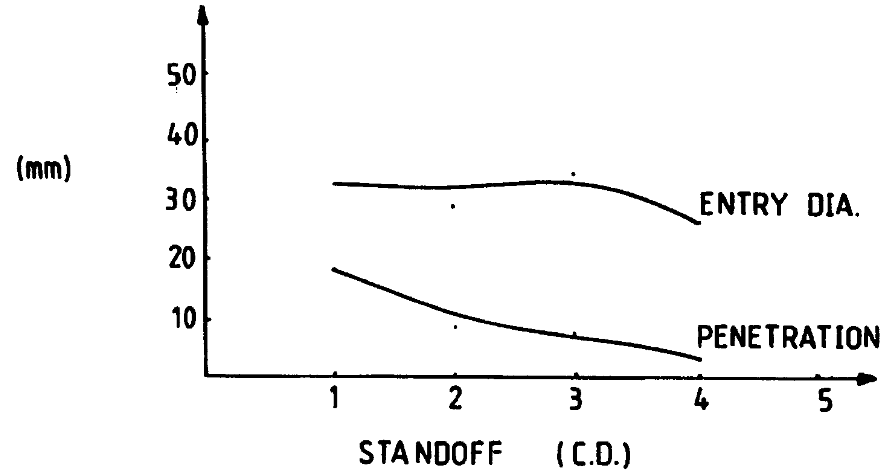


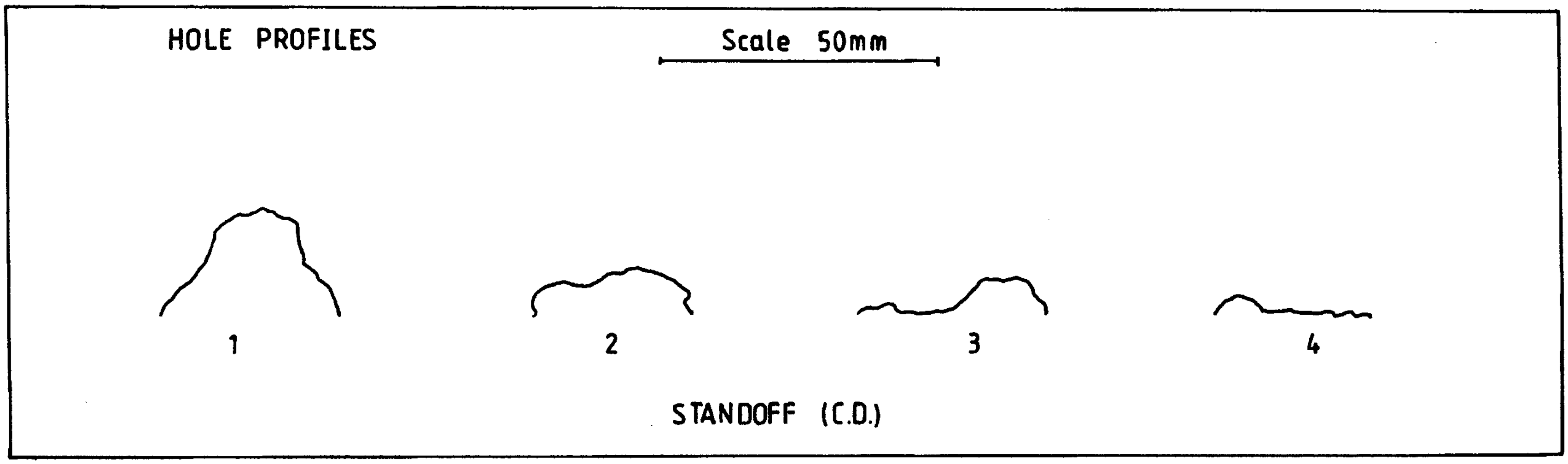


ϕ 38 mm x 45° PVC

STANDOFF (C.D.)	1	2	3	4
ENTRY DIAMETER (mm)	32	28	34	26
PENETRATION (mm)	18	8	7	3

CHARGE FILLED TO 25 mm HEAD HEIGHT
ALUMINIUM CASE
PVC 1mm THICK





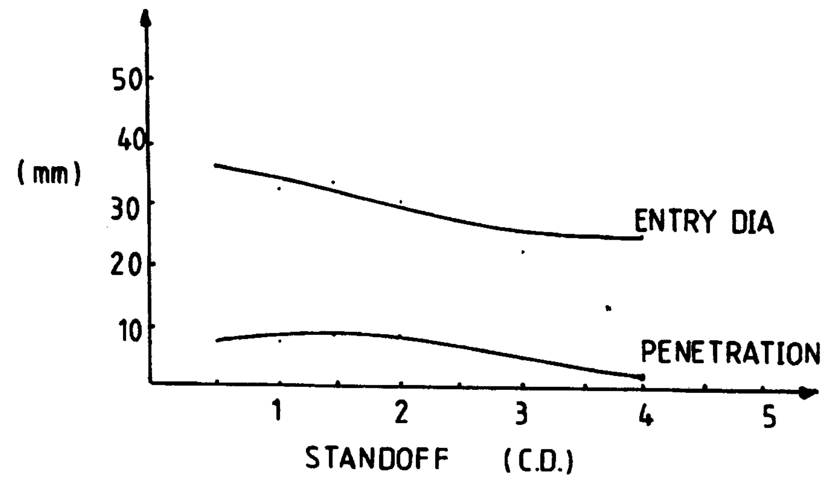
Φ 38 mm x R40 PVC

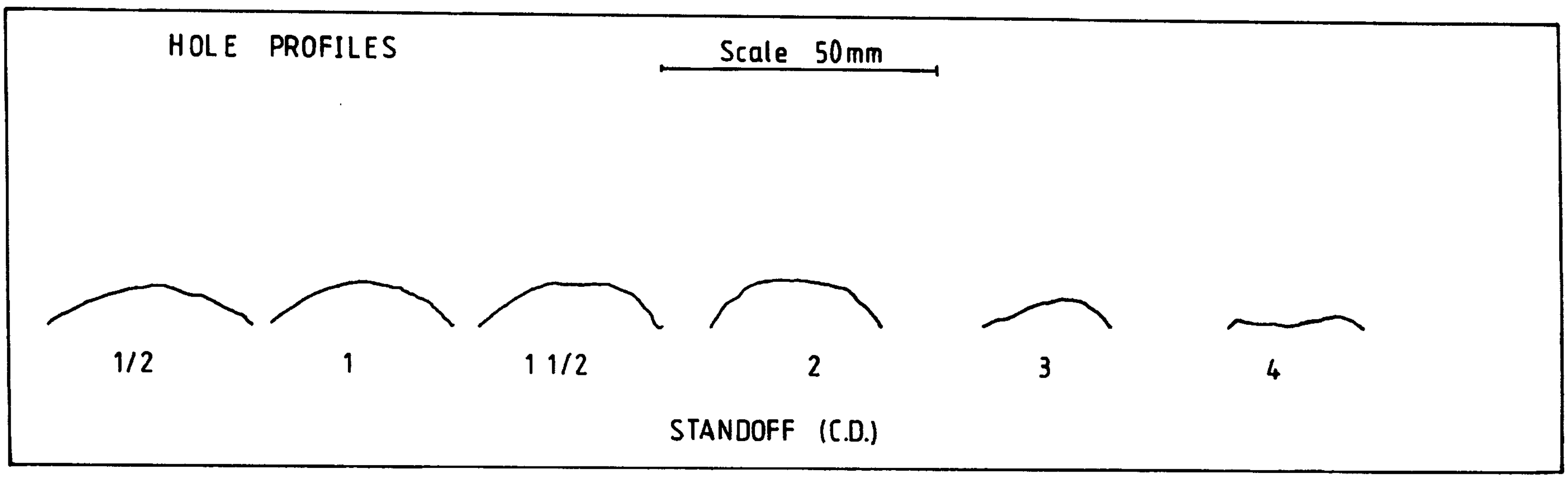
STANDOFF (C.D.)	1/2	1	1 1/2	2	3	4
ENTRY DIAMETER (mm)	36	32	33	30	22	25
PENETRATION (mm)	7	7	8	8	5	2

CHARGE FILLED TO 66 mm HEAD HEIGHT

ALUMINIUM CASE

PVC 1mm THICK

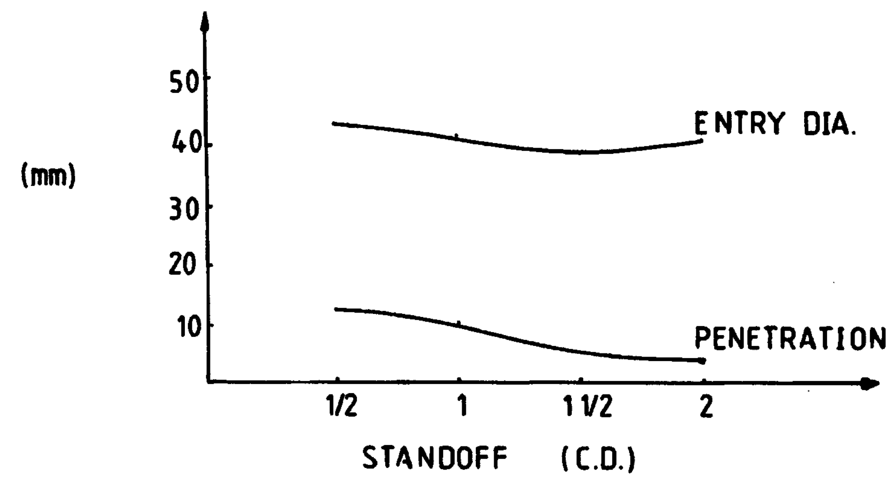


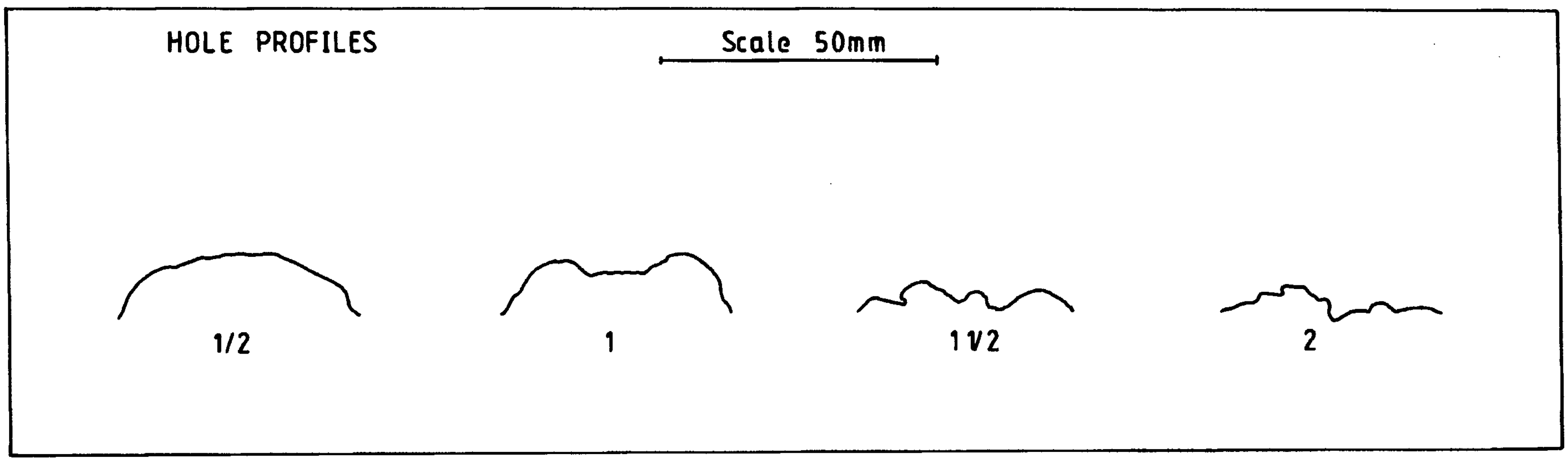


Φ 38mm x HEMISPHERICAL PVC

STANDOFF (C.D.)	1/2	1	1 1/2	2
ENTRY DIAMETER (mm)	43	41	38	40
PENETRATION (mm)	12	10	5	4

CHARGE FILLED TO 33mm HEAD HEIGHT
ALUMINIUM CASE
PVC 1mm THICK

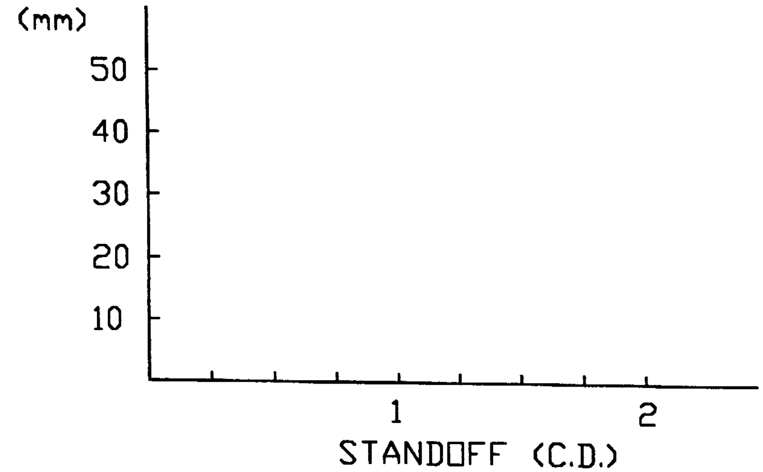


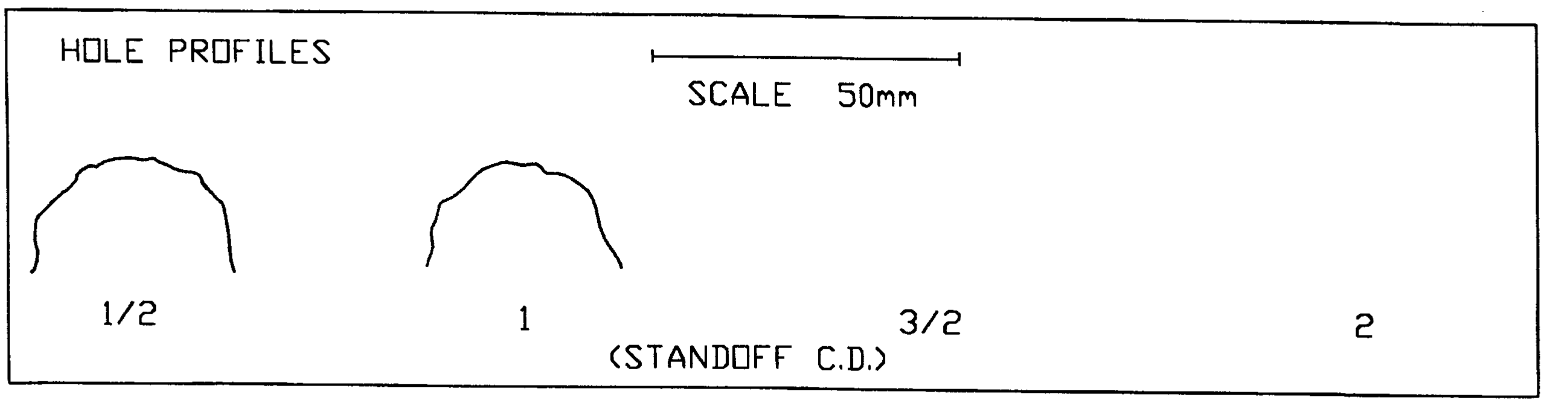


Ø38 × 90° PVC

STANDOFF (C.D.)	1/2	1	3/2	2
ENTRY DIAMETER (mm)	32	31		
PENETRATION (mm)	18	17		

CHARGE FILLED TO 52mm HEAD HEIGHT
PMMA CASE
LINER 1mm THICK

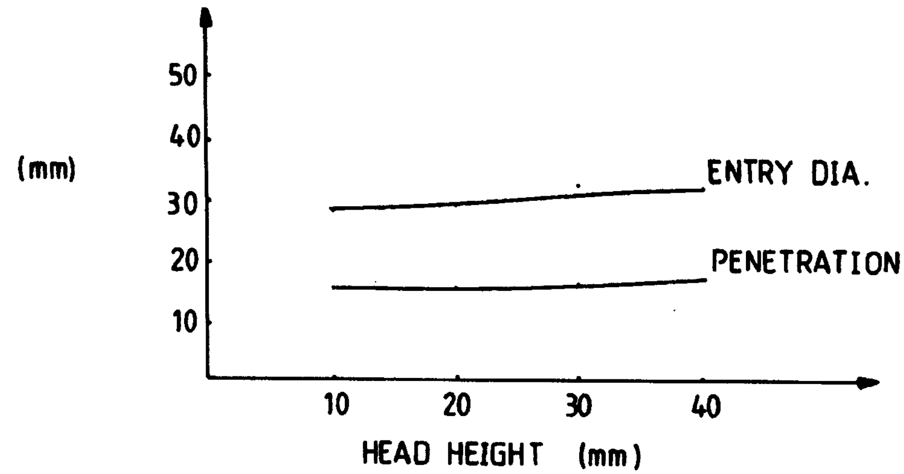


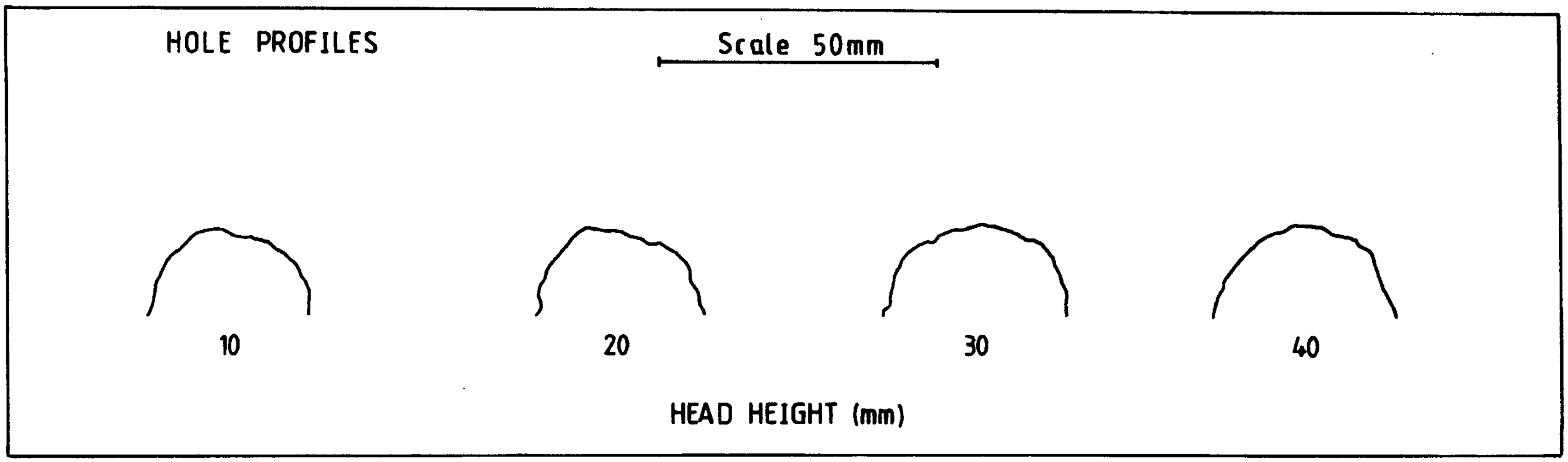


ϕ 38mm x 90° PVC

HEAD HEIGHT (mm)	10	20	30	40
ENTRY DIAMETER (mm)	28	29	32	32
PENETRATION (mm)	15	15	16	17

CHARGE AT 1 C.D. STANDOFF
ALUMINIUM CASE
PVC 1 mm THICK





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Darren McQueen

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18. DEFTEST DESCRIPTORS

Explosively formed projectiles, velocity measurements, flight characteristics, mathematical models.

19. ABSTRACT

This compendium assembles the results from a series of firings utilising different variations of Explosively Formed Projectiles (EFP'S). Variations were applied to the design of the liner, casing and explosive.
Following computer numerical modelling, short listed candidates were manufactured and fired into steel witness plates. The results were then tabulated accordingly. Also used during the firing phase was Flash radiography (FXR) to study velocity and flight characteristics.